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REPUBLIC OF KENYA

MINISTRY OF WATER AND IRRIGATION

ATHI WATER SERVICES BOARD (AWSB)

FEASIBILITY STUDY AND MASTER PLAN FOR DEVELOPING NEW WATER SOURCES FOR NAIROBI AND SATELLITE TOWNS

Preliminary EIA for the Selected Scenario: Nairobi Water Sources, Phases 1 & 2

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in association with :

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MANGAT, I.B. PATEL & PARTNERS

Contents

Executive Summary ... iv
1 Introduction ... 1
1.1 Master Plan for New Water Sources for Nairobi and Satellite Towns ... 1
1.2 Description of the Administrative, Policy and Regulatory Framework ... 2
1.3 World Bank Environmental and Social Safeguards Policies and Triggers ... 9
1.4 Consultations ... 12
2 Study Area ... 13
2.1 Geology ... 13
2.2 Topography and Drainage ... 13
2.3 Climate ... 14
2.4 Groundwater Resources ... 15
3 Development of Groundwater Well Fields ... 16
3.1 Potential Groundwater Well Fields ... 16
3.2 Scoping of Potential Impacts ... 17
3.2.1 Preliminary Exploration ... 17
3.2.2 Development of New Well Fields and Increased Extraction from existing Well Fields ... 21
4 Development of the Northern Collector Tunnel, Phase 1 ... 22
5 Downstream Reserve Flows ... 24
5.1 Environmental Flows ... 24
5.2 Environmental Flow Characteristics ... 27
5.3 Options for Environmental Flow Release ... 36
5.4 Indicators of Hydrologic Alteration ... 38
5.4.1 Range of Variability Approach ... 38
5.4.2 RVA Analysis ... 38
5.5 Compensation Flows ... 42
5.6 Recommendations for Reserve Flow Release ... 44
5.7 Impacts from Abstraction of Flows ... 46
5.8 Recommendations for Operating Rules ... 47
6 Cumulative Impacts ... 50
7 Upstream Catchment Areas ... 55
7.1 Catchment Protection ... 55
7.2 Water Quality ... 57
7.3 Importance of Tea Cultivation ... 58
8 Anticipated Impacts and Mitigation Measures ... 60
8.1 Protected Areas and Endangered Species ... 60
8.2 Impacts from Construction ... 62
8.2.1 Maragua Intake ... 62
8.2.2 Gikigie Intake ... 63
8.2.3 Irati Intake ... 65
8.2.4 Outlet Works ... 66
8.2.5 Excavated Material from the Northern Collector Tunnel ... 68
8.2.6 Transmission and Distribution Pipelines ... 69
8.3 Impacts from Operation ... 72
8.4 Impacts and Mitigation Measures ... 73
8.5 Aquatic and Riparian Environments ... 80
8.5.1 Impacts on Aquatic and Riparian Species ... 80
8.5.2 Impacts on Diseases ... 81
8.5.3 Interbasin Transfers ... 83
8.6 Analysis of Alternatives ... 84
9 Environmental Monitoring Plan ... 89
9.1 Draft Environment Management Plan ... 91

List of Tables

Table 4-1: Northern Collector Phase 1 Components 22

Table 5-1: Common Characteristics for each Flow Component for different disciplines 27

Table 5-2: Environmental Influences of Different Flow Components 29

Table 5-3: Characteristic Environmental Flow Components, Irati (RGS: 4BE6+4BE7, 1950-2010) 30

Table 5-4: Characteristic Environmental Flow Components for Gikigie (RGS: 4BE8, 1950-2010) 32

Table 5-5: Characteristic Environmental Flow Components for Maragua (RGS: 4BE9, 1950-2010) 34

Table 5-6: Characteristic Flows at Proposed Abstraction sites on Northern Collector 38

Table 5-7: Summary of Assessments of Hydrologic Alteration on flow rates for the proposed intake sites for Northern Collector Phase 1, comparing the release of 2 x Q95 Reserve Flows with Reserve Flows generated by variable abstraction and release procedures. 41

Table 5-8: Estimates for Required Minimum Downstream Reserve Flows **(m^3/s), NC Phase 1** 43

Table 5-9: Districts directly impacted by modified downstream flows, showing proportion of households using streams and estimated requirements for household use 43

Table 6-1: Average flows into Masinga Reservoir (m^3/sec), and potential changes following diversion of water to the Northern Collector Phase 1 53

Table 8-1: Impacts related to pipeline construction and operation 70

Table 8-2: Impacts due to Construction of weirs, intake structures and tunnels 74

Table 8-3: Impacts due to Operation of Weirs 75

Table 8-4: Yield of Existing Water Sources 84

Table 8-5: Potential New Water Sources Identified 85

Table 8-6: Water Demand Forecast: Nairobi City 85

Table 9-1: Pre-Construction Phase Information Requirements 93

Table 9-2: Environmental, Safety and Health Issues during Construction Phase 95

Table 9-3: Environmental Issues during Operational Phase 100

List of Figures

Figure 3-1. Possible location (red circle) of a 35,000 m3/day well-field in Kiunyu sector, near the Thika River. 17

Figure 3-2. Possible location (red circle) of a 30,000 m^3/day well-field in the north of Kiambu - NW of Ruiru area. 17

Figure 5-1: Example of flows during a relatively dry period - Irati River 1975-1976 (RGS 4BE6 and 4BE7 combined flows m3/sec) 26

Figure 5-2: Example of flows during a relatively wet period - Irati River 1997 - 1998 (RGS 4BE6 and 4BE7 combined flows) 27

Figure 5-3: Environmental Flow Components in Irati River (RGS: 4BE6 plus 4BE7), and flows recorded 1982 – 1985, illustrating Environmental Flow Components. 30

Figure 5-4: Annual Frequency of flows in each of the five EFC categories for Irati River (RGS: 4BE6 plus 4BE7), 1970-2010 31

Figure 5-5: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Irati River (RGS: 4BE6 plus 4BE7), (m^3/sec) 1970-2010 31

Figure 5-6: Environmental Flow Components in Gikigie River (RGS: 4BE8), and flows recorded 1982 – 1985, illustrating Environmental Flow Components 32

Figure 5-7: Environmental Flow Components in Gikigie River (RGS: 4BE8), and flows recorded 1996 – 1999, illustrating Environmental Flow Components, including large floods 33

Figure 5-8: Frequency of flows in the EFC categories for Gikigie River (RGS: 4BE8), 1970-2010 33

Figure 5-9: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Gikigie River (RGS: 4BE8), (m^3/sec) 1970-2010 Note: Compare average values for extreme low flows with the Q95 flow value of 0.052 m^3/sec. 33

Figure 5-10: Environmental Flow Components in Maragua River (RGS: 4BE9), and flows recorded 1984 – 1986, illustrating Environmental Flow Components 34

Figure 5-11: Frequency of flows in EFC categories for Maragua River (RGS: 4BE9), 1970-2010 35

Figure 5-12: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Maragua River (RGS: 4BE9), (m^3/sec) 1970-2010 35

Figure 5-13: **Irati intake: Flow Duration Curves. Natural Flows (green) and Downstream Release using 2xQ95 (red)** 36

Figure 5-14: Example of downstream flows following abstraction at proposed Irati Weir (2007-2008). A: Natural Flows and B: downstream flows after abstraction using (i) the recommended thresholds for variable extraction and (ii) release of 2xQ95 after abstraction (m^3/sec). 37

Figure 5-15: Frequency of EFC category High Flow Pulses before and after abstraction at Irati Weir, illustrating the difference between (A) Variable Release and (B) 2xQ95 for delivery of downstream Reserve Flows. 40

Figure 5-16: Summary of Assessments of Hydrologic Alteration on downstream flows at proposed intake sites: A). Variable abstraction and release, and B). 2 x Q95 for Reserve Flows 41

Figure 5-17: Locations in upper parts of Muranga North and South Districts (2009 National Census) through which Maragua, Gikigie and Irati Rivers flow. 44

Figure 6-1: Flows at Maragua RGS:4BE1, 2008-2010 (m^3/sec), illustrating characteristic seasonal patterns of flow with occasional periods of small floods and large floods (extreme low flows were not recorded during this period). 51

Figure 6-2: Flow Duration Curves at Maragua RGS:4BE1. Natural flows (green). Change following abstraction for Northern Collector and release of 2xQ95 (red). 51

Figure 6-3: Natural Flows at Maragua RGS:4BE1 during 1991 (m^3/sec), illustrating a period with extreme low flow. 52

Figure 6-4: Flows at Maragua RGS:4BE1 (1950-2010). Differences between the average monthly Natural flows and Modified flows with 2xQ95 released at Northern Collector intakes 52

Figure 6-5: Trends in international crude oil prices: Daily Brent Crude 2000-2011 (**US$ per barrel**), with best-fit trend line (power curve, R^2=0.801) extended to forecast till year 2017. 54

Figure 7-1: Northern Collector tunnel (including Phase 1 and Phase 2) and Thika Reservoir: Showing Protected Forest areas, National Park land, and rivers connected to the project 56

Figure 7-2: Land use adjacent to site of proposed Maragua Intake Weir, illustrating Smallholder Tea as dominant land use 57

Figure 8-1. Proposed site for the Maragua Intake Weir 63

Figure 8-2. Proposed site for the Gikigie Intake Weir 64

Figure 8-3. Location of the Proposed Gikigie Weir 65

Figure 8-4. Location of proposed Irati Weir and Intake Shaft: 66

Figure 8-5. Proposed site for Outlet Works above Thika Reservoir, showing riparian vegetation and surrounding tea plantation. 67

Annex

Annex 1: Indicators of Hydrologic Alteration

Annex 2: Proceedings of Stakeholders Workshop on 30th August 2011 held at Intercontinental Hotel, Nairobi.

Executive Summary

The Government of Kenya has received a credit from International Development Association (IDA) and the Agence Française de Développement (AFD), and intends to apply part of the proceeds for Consulting Services for Improving Water Security: Feasibility Study and Master Plan for Nairobi and Satellite Towns. The Water Sources Options Review, August 2011, compared six potential development scenarios on the basis of a range of technical and natural resources, economic, environmental, and social criteria. The development of bulk water sources to supply Nairobi and 13 satellite towns will impact on the general water resources balance in the region as a whole. The chosen development scenario, considered as the priority strategy to meet the 2017 water demand for Nairobi, includes two initial phases for which potential environmental impacts are assessed. These are:

- Phase 1: Groundwater development in Kiunyu area (2014) then in Ruiru area (2015);
- Phase 2: Northern Collector Tunnel Phase I from Maragua, Gikigie and Irati Rivers to Thika reservoir (2016)

This report focuses on the potential impacts relating to Phase 1 and Phase 2. Initial investment options for Phases 1 and 2 involve the development of two well fields at Kiunyu and Ruiru to supply groundwater (with an estimated total yield of 64,800 m3/d) and development of the Northern Collector Phase 1 (with an estimated yield of 138,240 m3/d). These developments are expected to increase Nairobi water supply by 50% over current supply levels by 2017.

The availability of potential groundwater resources was presented in the Review of Groundwater Resources, June 2011. A program of exploratory drilling is required in order to locate suitable high yielding formations and to give precise estimation of the well-fields' potential and to confirm the availability and suitability of this resource, significant use of this groundwater resource as part of the Nairobi water supply is expected. In the absence of more detailed plans, a full environmental assessment is not currently feasible. However, a scoping of potential impacts from the potential development of these well fields and associated distribution pipelines is presented. Potential impacts include:

1. Changes in groundwater contribution to base flows in rivers, and reduction in local water supplies available from springs and dug wells.
2. Degradation of aquifers.
3. Clearance of vegetation as a result of site establishment and associated impacts on agricultural land.
4. Impacts from drilling activities themselves, including noise, and accidental spillage.

Important mitigation measures include the installation of an increased network of river gauges and recording stations in order to fully cover the potentially impacted areas. Regular, daily monitoring and reporting of these river gauges will be necessary. At times when reduced base flows are considered to have occurred, or are likely, and where these fall below accepted Reserve Flow limits, it will be necessary to supply an increased flow from upstream resources in order to compensate for the reduced flow and to ensure

adequate downstream flows (environmental flows and compensation flows). Springs and wells in the areas within the geological strata affected by the proposed groundwater well fields also need to be identified and the yields monitored. Alternative, piped water supplies may need to be provided in cases where these water sources are impacted by reduced groundwater levels resulting from abstraction.

Longer term impacts will subsequently result from the operation of each of the well sites together with associated transmission and distribution pipelines. This will include:

- Compensation for loss of land.
- Compensation for loss of agricultural production and livelihoods.
- Operation of the pipeline wayleave in private land.
- Impacts resulting from potential pipeline leakage.

Phase 2 of the selected scenario for development of water sources for Nairobi includes the development of the Northern Collector Tunnel Phase I. This will enable the abstraction and diversion of water from Maragua, Gikigie and Irati Rivers to Thika reservoir. Implementation is planned by 2016.

The main environmental and socioeconomic impacts resulting from the Northern Collector Tunnel Phase 1 will be related to the diversion of water, and the resulting reduction in downstream flows in these rivers. This requires the assessment of the required downstream Reserve Flows, including both environmental flows and compensation flows. Such impacts are expected to be long-term. Additional impacts are related to the construction of the facilities themselves. However, these are expected to be local-level and relatively short-term impacts.

Downstream Reserve Flows are described, including compensation flows and the characteristics of environmental flows. Options for environmental flow release are outlined, including (i) the release of 2xQ95 Reserve Flows and (ii) the adoption of an alternative strategy that depends on the volume of incoming flow, with greater proportions being abstracted from higher flows together with the specification of a "hands off" flow below which no abstraction is allowed. The details of variable abstraction rates can be adapted at individual intake sites to cater for the needs of all users. Results of flow modelling show that abstractions will reduce the frequency of middle-level and high-level flows and increase the frequency of low-level flows. The general absence of high flow pulses, small floods and large floods, associated with release of 2xQ95 Reserve Flows will result in inevitable long-term changes to downstream riverine and riparian environments.

Operational procedures will need to be established so that, under periods with naturally low flows (e.g. extreme low flows), sufficient flows are allocated to:

a) Cater for downstream demands from communities, households, agriculture (crops and livestock), and commercial or industrial requirements,

b) Provide environmental flows of sufficient quantity to prevent critical decline of downstream aquatic environments,

c) Ensure the maintenance of water quality (including the requirements related to sewage treatment and disposal), and

d) Provide some flow for Nairobi water supplies whilst taking account of available storage in reservoirs. Rationing of water to all consumers may need to be considered under such circumstances.

An important recommendation is that all river flows must be monitored and reported on a regular daily basis both above and below each of the weirs and intake structures, as well as at sites downstream. Information on flows will then be available to form the basis for day-to-day operational management decisions.
Regular monitoring and updating of downstream water abstraction and use will need to be carried out. This includes, for example, the use of water by households and communities, or for use as irrigation supplies and commercial/industrial use. This should include both currently licensed and unlicensed abstractions. This information will need to be fed into regular operating procedures in order to optimise the use of available water resources and continue to provide environmental flows capable of maintaining downstream environments and critical environmental services.
Cumulative impacts are considered, and are expected to include the following primary considerations:

- Reduced flows as a result of diversion of a majority of the flows originating from the Aberdares at Irati, Gikigie and Maragua intakes to the Northern Collector, resulting in:
- Reduction in the flow reaching Masinga Reservoir of 3.17% on an annual basis, and therefore a reduced flow available for hydroelectric power generation.
- Some short periods or single days with potentially zero flow (0.33% of daily flows). These periods can be mitigated by the release of higher flows from the Northern Collector intake sites over selected periods in order to prevent unacceptable low flows downstream.
- Less flow available for use by future agricultural activities in selected downstream areas (irrigation) that can be expected to be in demand in order to provide some of the additional food required by the increasing population of Nairobi.

Catchment protection is an important component of the overall management of water resources. Impacts related to catchment protection in the Irati, Gikigie and Maragua catchments are considered to be manageable issues with no negative impacts. Major parts of the catchments of the proposed Northern Collector abstraction sites are included within the protected areas of the Aberdares, including the Aberdare National Park and neighbouring Aberdare Forest Reserve. Significant parts of the catchments are therefore considered to be under a “high protection" status. Outside of the protected areas, land cover of managed land is predominantly tea plantation. The deep roots and ground cover provided by tea results in relatively good soil and water conservation. Downstream of the intake weirs it is also recommended that regular land management and control measures will be required for catchment protection, in particular in order to reduce the risks of soil erosion. Where possible this should be combined with local on-farm water harvesting measures and agricultural practices such as Conservation Tillage.
The Maragua, Gikigie and Irati Rivers each provide riparian vegetation along their length. Over this stretch of river no specific important ecosystems are identified with the exception of this riparian vegetation that provides an important natural corridor. Reduced flows will have an overall negative impact on the riparian vegetation cover, with expected long-term effects including reduced habitats, degraded stream bank stability, and potential changes in the depth of the water table. Combined with expected increase in clearance for agricultural activities, the long-term changes to riparian vegetation are expected to have a negative impact on the species diversity and populations of many bird, small mammal and other wildlife species using these resources. As a result, population numbers of some bird species are expected to decline downstream of the intake structures. Impacts are expected to reduce in intensity further downstream as other

tributaries merge with the main rivers and the effective catchment area increases, providing some seasonal hydrological changes, including small floods and large floods. Potential negative impacts that can be expected from construction of the proposed intakes at Irati, Gikigie and Maragua, together with the construction of the Northern Collector Tunnel include:

a) Land acquisition and loss of cultivated areas, especially smallholder tea, in areas adjacent to the Intake Sites.

b) Soil erosion resulting from site preparation and construction activities, including the construction of weirs, tunnels and pipelines.

c) Change in local topography during site preparation/grading.

d) Pollution from machinery and construction activities.

e) Construction of access roads, temporary settlement and workmen's camps, and permanent offices and settlement required to maintain and run each of the weirs.

f) Disposal of rock and other material excavated from the Northern Collector Tunnel and access shafts.

g) Pollution from machinery and construction activities, including accidental spillage.

h) Possible impacts on hydrogeology as a result of tunnelling.

Construction activities will result in significant volumes of excavated material derived from the rock excavated from the tunnels. No areas for "spoil" dumps have been clearly identified. Disposal of the material from the tunnel in dumps will have inevitable negative impacts. It is strongly suggested that instead of considering the excavated material as spoil, requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material, including for example the making of blocks/bricks for buildings. Long-term storage of excavated material that is not used for other purposes should be included in the management or rehabilitation of unused or abandoned quarry sites.

The installation of the necessary transmission and distribution pipelines will result in potential disturbance to natural habitats, to agricultural land and to communities along the pipeline routes. Habitat restoration and maintenance will be required after pipeline construction is completed. Impacts on local flora and fauna will be long-term if habitat restoration is not carried out. Most of the pipelines will be in settled areas that are already environmentally altered and land will need to be acquired. Positive impacts from pipeline construction include the creation of job opportunities, as well as the potential for improved habitats for local wildlife species along the wayleave if this strip of land is managed appropriately. Compensatory plantation of trees and other vegetation should be carried out at the rate of a minimum of five trees planted for every tree cut. Compensation of affected land and property assets lost should be provided. There may also be a requirement for provision of new or modified infrastructure to compensate for loss or impacts to existing facilities (including roads, schools, health facilities, market areas etc.). Consideration should also be given to ensure that communities traversed by the pipelines are fully provided with piped water supplies.

1 Introduction

1.1 Master Plan for New Water Sources for Nairobi and Satellite Towns

The Government of Kenya has received a credit from International Development Association (IDA) and the Agence Française de Développement (AFD), and intends to apply part of the proceeds for Consulting Services for Improving Water Security: Feasibility Study and Master Plan for Nairobi and Satellite Towns.

The present document is the Preliminary EIA for the Selected Scenario, Nairobi Water Sources prepared by the Consultant Egis Bceom International in association with Mangat I.B. Patel & Partners according to the Contract with Athi Water Services Board (AWSB) for the consulting services related to the Feasibility Study and Master Plan for Developing New Water Sources for Nairobi and Satellite Towns.

To date, the following Reports / Working Papers have been submitted by Egis Bceom International / Mangat I.B. Patel & Partners.

- Inception Report, February 2011
- Working Paper No. 1 – Preliminary Review and Update of Scenarios for Water Supply to Nairobi – February 2011
- Working Paper No. 2 – Surface Water Hydrology – March 2011
- Working Paper No. 3 – Water Demand Report – April 2011
- Water Sources Options Review Report (Draft Version 01) – 23rd May 2011
- Review of Groundwater Resources – June 2011
- Water Sources Options Review Report (Version 02) – August 2011

The Water Sources Options Review Report (August 2011) compared six potential development scenarios on the basis of a range of technical and natural resources, economic, environmental, and social criteria. Comparison of each water source development scenario showed that overall Scenario 2 ranked higher than the other scenarios. These chosen development options are considered as the priority strategy to meet the 2017 water demand for which preliminary design is required. The development of bulk water sources to supply Nairobi and 13 satellite towns will impact on the general water resources balance in the region as a whole.

The selected scenario for development of water sources for Nairobi includes the following phases:

- Phase 1: Well fields development in Kiunyu area (2014) then in Ruiru area (2015);
- Phase 2: **Northern Collector Tunnel Phase I from Maragua, Gikigie and Irati Rivers to Thika reservoir** (2016)
- Phase 3: Northern Collector Tunnel Phase II connecting South Mathioya, Hembe, Githugi, and North Mathioya Rrivers to **Northern Collector Phase 1** and Thika Reservoir (2018);
- Phase 4: Ndarugu 1 Dam with natural inflow (2024);
- Phase 5: **Diversion and transfer from Chania River to Komu River to supplement** inflow to Ndarugu 1 Reservoir (2031).

This report focuses on the potential impacts relating to Phase 1 and Phase 2: the development of Well Fields in Kiunyu and Ruiru areas, and the development of the Northern Collector Phase I to Thika Reservoir.

The mobilisation of these additional water resources will require additional water transmission facilities towards Nairobi City. These facilities are linked to new water treatment facilities.

This report investigates potential impacts resulting from the potential developments in Phase 1 and Phase 2. Initial investment options for Phases 1 and 2 involve the development of two well fields at Kiunyu and Ruiru to supply groundwater (with an estimated total yield of 64,800 m^3/d) and development of the Northern Collector Phase 1 (with an estimated yield of 138,240 m^3/d). These developments will increase Nairobi water supply by 50% over current supply levels by 2017. Groundwater can be developed faster, but it is not yet a proven resource and requires further investigation that will be funded under WaSSIP additional financing. It is expected that Phase 1 of the Northern Collector Project, and the development of the Well fields in the Kiumyu and Ruiru areas, will receive funding from the Water and Sanitation Service Improvement Project (WaSSIP) Additional Financing (AF) project which is being financed by the World Bank.

1.2 Description of the Administrative, Policy and Regulatory Framework

National Environmental and Social Management Requirements

This section describes the institutional, legal and policy framework for environmental and social requirements in Kenya, the relevant World Bank safeguard Operational Policies applicable to the project as well as the international laws and conventions that bear relevance to the implementation of this project.

The Legal, Regulatory and Policy Framework

Constitutional provisions

Kenya now has a new Supreme law in form of the New Constitution which was promulgated on the 27th of August 2010 and which takes supremacy over all aspects of life and activity in the New Republic. With regard to environment, Section 42 of the Constitution states as follows:

Every person has the right to a clean and healthy environment, which includes the right –

(a) *To have the environment protected for the benefit of present and future generations through legislative and other measures, particularly those contemplated in Article 69; and*

(b) *To have obligations relating to the environment fulfilled under Article 70.*

In Sections 69 and 70, the Constitution has inter alia identified National Obligations in respect of the environment and Enforcement of Environmental Rights respectively as follows:-

Section 69 (1): The State shall –

a) *Ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensure the equitable sharing of the accruing benefits;*

b) *Work to achieve and maintain a tree cover of at least ten per cent of the land area of Kenya;*

c) *Protect and enhance intellectual property in, and indigenous knowledge of, biodiversity and the genetic resources of the communities;*

d) *Encourage public participation in the management, protection and conservation of the environment;*

e) *Protect genetic resources and biological diversity;*

f) *Establish systems of environmental impact assessment, environmental audit and monitoring of the environment;*

g) *Eliminate processes and activities that are likely to endanger the environment; and*
h) *Utilize the environment and natural resources for the benefit of the people of Kenya.*

Section 69 (2) Every person has a duty to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources.
Section 70 provides for enforcement of environmental rights thus:
(1) If a person alleges that a right to a clean and healthy environment recognized and protected under Article 42 has been, is being or is likely to be, denied, violated, infringed or threatened, the person may apply to a court for redress in addition to any other legal remedies that are available in respect to the same matter.
(2) On application under clause (1), the court may make any order, or give any directions, it considers appropriate–

a) *To prevent, stop or discontinue any act or omission that is harmful to the environment;*
b) *To compel any public officer to take measures to prevent or discontinue any act or omission that is harmful to the environment; or*
c) *To provide compensation for any victim of a violation of the right to a clean and healthy environment.*

(3) For the purposes of this Article, an applicant does not have to demonstrate that any person has incurred loss or suffered injury.
Essentially, the new Constitution has embraced and provided further anchorage to the spirit and letter of EMCA 1999 whose requirements for environmental protection and management have largely informed Sections 69 through to 71 of the document. In Section 72 however, the new constitution allows for enactment of laws towards enforcement of any new provisions of the Supreme Law.

Vision 2030
Kenya Vision 2030 is the current national development blueprint for period 2008 to 2030 and was developed following on the successful implementation of the Economic Recovery Strategy for Wealth and employment Creation which saw the country's economy back on the path to rapid growth since 2002. Gross Domestic Product (GDP) growth rose from 0.6% to 7% in 2007, but dropped to between 1.7% and 1.8% in 2008 and 2009 respectively. The objective of the vision 2030 is to transform Kenya into a middle income country with a consistent annual growth of 10 % by the year 2030. The 2030 goal for urban areas is to achieve "a well-housed population living in an environmentally-secure urban environment." This will be achieved by bringing basic infrastructure and services – roads, street lights, water and sanitation facilities, storm water drains, footpaths, and others – to informal settlements. By strengthening tenure security in informal settlements, the Kenya Informal Settlements Improvement Program (KISIP) will also foster private investment in housing and in businesses. The government's Medium-Term Plan 2008–2013, which presents the first five-year program to implement the Vision 2030, also specifies improving urban informal settlements as a priority. One of its flagship projects is installation of physical and social infrastructure in slums in 20 urban areas to make them formal settlements, permit construction of permanent houses, and attract private investment. The proposed KISIP will directly contribute to this goal.

Environment Management and Coordination Act, 1999
There are several laws and regulations that will govern the implementation of this project at the national level. However the most prominent legislation that will be evoked is the EMCA 1999. EMCA 1999 was enacted in 2000 to harmonize environmental legislation previously scattered among 77 national laws. As the principal environmental legislation in Kenya,

EMCA sets the legal framework for environmental management. Its core elements are as follows:

Creation of a National Environmental Management Authority (NEMA)

EMCA 1999 allows for formation of the National Environmental Management Authority (NEMA) as the body charged with the overall coordination of environmental protection in Kenya, mainly through setting and harmonizing standards for environmental quality. NEMA was established in 2001, and is headed by a Director General appointed by the President. The Director General is assisted by several directors in charge of Enforcement, Education, and Policy, who in turn are assisted by Assistant Directors and Senior Officers.

To facilitate coordination of environmental matters at a District level, EMCA 1999 allows for the creation of District Environmental Committees chaired by respective District Commissioners, and the appointment of a District Environmental Officer who oversees environmental coordination and is also secretary to the DEC.

Environmental Assessments

Section 58 of EMCA requires that an Environmental Impact Assessment precedes all development activities proposed to be implemented in Kenya. This requirement was operationalized by NEMA through its publication of the Guidelines for the Conduct of EIAs and Environmental Audits (Kenya Gazette Supplement No. 56 of 13th June 2003). The framework for environmental assessment in Kenya and a description of types of development that should be subjected to environmental impact assessment are outlined in Legal Notice 101 and the Second Schedule of EMCA respectively.

Legal Notice 101 is silent on the minimum size threshold for projects triggering EIA requirements. However Section 10(2) (Part II) of Legal Notice 101 allows for the approval of proposed projects at the ‘Project Report’ Stage. This Section is used by NEMA to grant Environmental Licenses to small projects without the requirement for a full-scale EIA.

Environmental Audits

Under Sections 68 and 69, EMCA requires that all ongoing projects be subjected to annual environmental audits as further expounded in Regulation 35 (1) and (2) of Legal Notice 101 of June 2003. Part V of the Legal Notice 101 defines the focus and scope of Environmental Audit studies as including an appraisal of all the project activities, within the perspective of environmental regulatory frameworks, environmental health and safety measures and sustainable use of natural resources.

Sectoral Coordination in Environmental Protection

Among other functions, EMCA mandates NEMA to regularly review and gazette standards and regulations for environmental quality as a way of guiding activity in all sectors. Further, in recognition that EMCA is an umbrella law coordinating diverse sectoral statutes, all of which are still in force, the Legal Notice 101 of EMCA requires that the respective sectors be consulted as ‘Lead Agencies’ in making decisions pertaining to environmental assessment for projects in respective sectors. Therefore to ensure that NEMA does not approve projects that contradict sector policies and legislation, all EIA reports are subjected to review by the relevant sector in their capacity as Lead Agency. Their opinions have a strong bearing on the final decision arrived at by NEMA.

The Water Act 2002

Sessional Paper no. 1 of 1999 on the National Water Policy on Water Resources Management and Development provides policy direction for the water sector.

The policy directions include:

- *Preservation, conservation and protection of available water resource;*
- *Sustainable, rational and economical allocation of water resources;*

- *Supplying adequate amounts of water meeting acceptable standards for the various needs;*
- *Ensuring safe wastewater disposal for environmental protection;*
- *Developing a sound and sustainable financial system for effective water resources management, water supply and water borne sewage collection, treatment and disposal.*

The Water Act 2002 forms the principal legislation governing protection and management of water resources in Kenya. This legislation provides diverse safeguards to regulate water development as follows:

Ownership of Water Resources

In an effort to control abuse and irrational allocation, Section 3 of the Water Act vests the entire national water resource base to the State, which then authorizes utilization. Abstraction is regulated under Section 25 of the Water Act 2002 with the Water Resource Management Authority (WRMA) assuming responsibility of issuing Water Permits subject to conditions as specified in Sections 27 to 43 and the Second Schedule of the Act. Decisions on the granting of water permits will take account of other existing lawful uses, efficient and beneficial use of water in the public interest, requisite catchment management strategies, potential impact of abstraction on the water resource and other users, quality considerations, and strategic importance of the proposed water use among other factors.

All the WSBs will be required to request for permission to abstract water from the rivers targeted as intakes by making a formal application to WRMA.

Requirements for Environmental and Social Impact Assessment

It is a requirement under Section 29(4) of the Water Act "for all proposed water projects to be subjected to public consultation and possibly an Environmental Impact Assessment Report" for review by NEMA through Lead Agencies including District Environmental Committees. Further, in order to complement the Water Act, NEMA sets guidelines for waste disposal into natural waters and the environment and also spells out penalties for the pollution of water. All the WaSSIP AF projects will be subjected to EIA following screening to determine if a Full Scale EIA is required or a project report depending on the project nature and category. Similarly all the sewerage plants will be required to conform with the waste disposal standards into natural waters and the environment as provided for in the NEMA guidelines.

Service Provider Agreements (SPAs)

Section 73(1) of the Water Act 2002 requires Water Service Boards (WSBs) and other Licensees of the Water Services Regulatory Board to make rules for provision of water services and tariff levels. The WSBs are required to enter into SPAs with water service providers, which specify the approved tariff levels and performance targets for the project. This includes measures to ensure that those unable to pay for water are not denied access to clean water.

Land Control Act CAP 406

This law provides for the control of transactions in agricultural land, especially the machinery of the Land Control Boards. However of interest in this report is the consideration in granting or refusal of consent by the Board based on the impact the transaction is likely to have on the maintenance or improvement of standards of good husbandry within the specific agricultural area.

Government land is land owned by the Government of Kenya under the Government Lands Act (Cap. 280). This includes, for example, Forests, gazetted National Parks and Reserves. The Government Lands Act allows the president, through the commissioner of lands, to allocate any unalienated government land to any individual. In practice, such allocations have often been made without proper regard to social and environmental factors.

Trust land is land held and administered by various local government authorities as trustees under the constitution of Kenya and the Trust Land Act (Cap. 288). National Reserves and local sanctuaries as well as county council forest reserves, are in this category. Individuals may acquire leasehold interest for a specific number of years in trust land and can (in theory) be repossessed by the local authorities should the need arise. Local authorities should retain regulatory powers over trust land.

Private land is land owned by private individuals under the Registered Land Act (Cap. 300). On registration as the landowner, an individual acquires absolute ownership on a freehold basis. The use of private land may, however, be limited by provisions made in other legislation, such an Agriculture Act (Cap. 318). For instance, to protect soils the clearing of vegetation may be prohibited or the planting of trees required. Land preservation orders issued by the director of agriculture can cover a whole range of other measures.

The Wildlife Conservation and Management Act, Cap 376

This Act provides for the protection, conservation and management of wildlife in Kenya. Nature Reserves and National Parks are controlled by the Kenya Wildlife Service under the Wildlife (Management and Co-ordination) Act of 1976. The common feature with all land reserved for use by wildlife is that its conversion to any other form must be approved by Parliament.

Public Health Act Cap 242

The Public Health Act provides for the protection of human health through prevention and guarding against introduction of infectious diseases into Kenya from outside, to promote public health and the prevention, limitation or suppression of infectious, communicable or preventable diseases within Kenya, to advice and direct local authorities in regard to matters affecting the public health to promote or carry out researches and investigations in connection with the prevention or treatment of human diseases. This Act provides the impetus for a healthy environment and gives regulations to waste management, pollution and human health. The Public Health Act regulates activities detrimental to human health. The owner(s) of the premises responsible for environmental nuisances such as noise and emissions, at levels that can affect human health, are liable to prosecution under this act. An environmental nuisance is defined in the act as one that causes danger, discomfort or annoyance to the local inhabitants or which is hazardous to human health.

This Act controls the activities of the project with regard to human health and ensures that the health of the surrounding community is not jeopardized by the activities of the project such as water development.

Physical Planning Act

This Act provides for the preparation and implementation of physical development plans for connected purposes. It establishes the responsibility for the physical planning at various levels of Government in order to remove uncertainty regarding the responsibility for regional planning. A key provision of the Act is the requirement for Environmental Impact Assessment (EIA). This legislation is relevant to the implementation and siting of sewerage plants in pilot urban centres as identified in the project document.

It provides for a hierarchy of plans in which guidelines are laid down for the future physical development of areas referred to in a specific plan. The intention is that the three-tier order plans, the national development plan, regional development plan, and the local physical development plan should concentrate on broad policy issues.

The Act calls for public participation in the preparation of plans and requires that in preparation of plans proper consideration be given to the potential for socio-economic development needs of the population, the existing planning and future transport needs, the physical factors which may influence orderly development in general and urbanization in particular, and the possible influence of future development upon natural environment.

The Local Government Act

The Local Government Act, CAP 265, gives the Local authorities powers over sanitation of their respective urban centres. This Act empowers the Municipal Authority to provide and maintain sanitation and sewerage services and to take measures to control or prohibit factories and industries from emitting smoke, fumes, chemicals, gases, dust, smell, noise, vibrations or any danger, discomfort or annoyance to the neighbourhood and to control disinfections particularly using cyanide. They are empowered to punish those disrupting sanitation or sewerage lines and can compel owners to construct sewage line into the systems and drainages.

Trends in Institutional and Legal Framework in Kenya

The WaSSIP AF project has been conceived and developed within the context of recently concluded legal reforms in both the forestry and water sectors in Kenya.

Reforms in the Water Sector

The enactment of the Water Act 2002 has driven the implementation of the national water policy. Towards this, a National Water Resources Management Strategy (NWRMS 2005-2007) was released in December 2004 to provide a clear, accountable and transparent roadmap for assessing, maintaining, enhancing, developing and managing the limited available, renewable, freshwater resources using an integrated approach and on a sustainable basis.

In line with the Water Act 2002, new institutions have been formed to take responsibilities formerly held by the Ministry of Water. These new institutions include:

> **The Water Resource Management Authority (WRMA)**
> A body corporate charged (under Section 8(1) of the Water Act 2002) with the overall responsibility of managing the water resources of the country;
>
> **Water Service Boards (WSBs)**
> The WSBs are responsible for ensuring adequate access to water and sanitation services within their jurisdictions. Where government assets exist they will be owned by the WSBs and operated by Water Service Providers (see below). The WSB is the primary agent of service quality oversight;
>
> **Water Services Regulatory Board (WSRB)**
> Mandated as the national regulator with responsibility for providing guidelines on tariff setting and quality standards. The WSRB also is responsible for issuing licenses to WSBs;
>
> **Water Services Trust Fund (WSTF)**
> For providing financial support to the rural water sector through grant finance for capital investments; and Water Service Providers to provide water services to consumers, ranging from public urban utilities, small private network operators in rural areas and community managed self supply through water users' associations.

WRMAs will be administered based on new boundaries that do not follow the government administrative boundaries. WRMA has divided the country into 6 regions and 25 sub regions based on catchments. Each region has a regional officer and each sub-region has a sub-regional officer. In addition, the Ministry of Water and Irrigation (MWI) is currently working to realign and rationalize the institutional functions and responsibilities based on the 2002 National Water Act so as to eliminate duplications and overlaps of roles and responsibilities among different institutions. The MWI has been downsized and many of the district water offices' responsibilities and tasks have already been taken by the WRMA and the Water Services Board.

Relevant Institutions

The Ministry of Water and Irrigation (MoWI)

The Ministry of Water and Irrigation (MWI) is the ministry in charge of the water sector and is therefore responsible for the overall management of water resources and general government policy on the water sector in the country. The Ministry was established in January 2003 with the goal of conserving, managing and protecting water resources for socio-economic development.

Under the water sector reforms, the Ministry transferred management of and operation of water services to the Water Services Regulatory Board (WASREB) from mid 2005. The Director of water was the person in charge of water services in the ministry but these powers and duties were transferred to the regional water service boards that are now licensed by the WASREB to provide water services in different regions across the country. The ministry and other state corporations that were involved in water supply such as the National Water Conservation and Pipeline Corporation also transferred their water supply facilities to these regional water service boards. NGOs, CBOs and any other community self help groups are required to enter into agreements with the respective regional water service boards with regard to use of water supply facilities owned by the community organisations.

Water Resources Management Authority (WRMA)

The Water Resources Management Authority (WRMA) was formed as one of the water sector bodies under the water sector reforms; the body was established under the Water Act 2002. The overall mandate of WRMA is to protect and conserve water resources. Water resources for purposes of the Water Act include lakes, ponds, swamps, streams, marshes, watercourses or anybody of flowing or standing water both below and above the ground.

The functions of the WRMA include planning, management, protection and conservation of water resources. The WRMA is also authorized to receive and determine applications for water permits and monitor their compliance. There are currently six established regional offices in Kenya these are Athi catchment area in Machakos, Tana catchment area in Embu, Rift Valley catchment area in Nakuru, Lake Victoria South catchment area in Kisumu, Lake Victoria North catchment area in Kakamega and Ewaso Nyiro North catchment area in Nanyuki. The WRMA responsibilities extend to the management of water catchments. The Water Act establishes the Catchment Area Advisory Committees whose principal functions are to advise the WRMA on water resources conservation, use and apportionment at the catchment levels.

Water Services Regulatory Board (WASREB)

The Water Services Regulatory Board is established under the Water Act and was operationalized in March 2003. The functions of the WASREB include the issuance of licences to Water Service Boards and to approve service provision agreements concluded between Water Service Boards and Water Service Providers. The Water Service Providers are the agencies that directly provide water and sanitation services to consumers. The WASREB is responsible for ensuring that water services and supply are efficient and meet expectations of consumers through regulation and monitoring of Water Service Boards and Water Service Providers. To standardize service provision, the Board has the responsibility of developing among others, tariff guidelines.

The Board is therefore supposed to oversee the implementation of policies and strategies relating to provision of water and sanitation services, these policies include the National Water Services Strategy (2007 -2015), Pro-Poor Implementation Plan for Water Supply and Sanitation (refer to the popular versions of these documents prepared by COHRE & Hakijamii Trust), the specific functions of the WASREB include:

- *Providing information about water and sanitation services.*
- *Regulating the provision of water and sanitation services; this is done through such methods as setting standards for the provision of water services, monitor compliance of facilities for water supply with the set standards.*

- *Licensing Water Service Boards such as the Athi Water Services Board and other regional water service boards and approving their appointed Water Service Providers through service provision agreements.*
- *Setting the rules, establishing standards guidelines and monitoring the performance of Water Service Boards and Water Service Providers and enforcing regulations.*
- *Establishing technical, water quality and effluent disposal standards.*

Water Services Trust Fund (WSTF)

The Government of Kenya, through the Ministry of Water and Irrigation established the Water Services Trust Fund (WSTF) under the Water Act 2002 to channel funding for its long-term objectives of developing water and sanitation services in areas of Kenya without adequate water. The main objective of the WSTF is to assist in financing capital costs of providing services to communities without adequate water and sanitation services. The WSTF focuses on reaching those areas that are underserved or not served at all such as informal settlements, the priority being given to poor and disadvantaged groups. The projects are funded through direct allocation by the Government and donations and grants that may be received from bilateral and multilateral development partners, organisations and individuals.

Water Appeals Board

The Water Appeals Board is established under the Water Act to adjudicate disputes within the water sector. The Appeals Board is made up of three persons, one appointed by the President on advice of the Chief Justice and two others appointed by the Minister for Water and Irrigation. The Water Appeals Board can hear and determine appeals arising from the decision of the Minster of Water and Irrigation, the WASREB and the Water Resources Management Authority (WRMA) with respect to the issuance of permits or licensees under the Water Act.

Water Services Boards (WSB)

Water Services Boards (WSBs) are constituted under the Water Act 2002. The WSBs are responsible for the provision of water and sewerage services within their areas of coverage and are licensed by the WASREB. The WSBs are also responsible for contracting Water Services Providers (WSPs) for the provision of water services. WSB and WSP enter into service provision agreements that include but not limited to the supply area, development, rehabilitation and maintenance of water and sewerage facilities of the WSBs. The WSBs are responsible for the review of the water services tariffs proposals from WSP before submission to WASREB for consideration.

There are currently eight (8) established WSBs namely: Athi Water Services Board, Tana Water Services Board, Coast Water Services Board, Lake Victoria South Water Services Board, Lake Victoria North Water Services Board, Northern Water Services Board, Rift Valley Water Services Board and Tanathi Water Services Board.

1.3 World Bank Environmental and Social Safeguards Policies and Triggers

In this section, the World Bank's environmental and safeguards policies and their applicability are discussed. The World Bank Safeguard Policies are:

1) *Environmental Assessment (OP/ BP 4.01,)*
2) *Natural Habitats (OP/ BP 4.04,)*
3) *Forestry (OP/ BP 4.36)*
4) *Pest Management (OP/BP 4.09)*
5) *Physical Cultural Resources (OP/BP 4.11)*
6) *Indigenous Peoples (OP/BP 4.10)*
7) *Involuntary Resettlement (OP/BP 4.12)*
8) *Safety of Dams (OP/BP 4.37)*

9) *Projects on International Waterways (OP/BP 7.50)*
10) *Projects in Disputed Areas (OP/BP 7.60,)*

For the Nairobi Water Sources Phase 1 project, only the following Bank policies are triggered.

1) *Environmental Assessment (OP/BP 4.01,)*
2) *Involuntary Resettlement (OP/BP 4.12)*
3) *Safety of Dams (OP/BP 4.37)*
4) *Physical Cultural Resources (OP/BP 4.11)*

Environmental Assessment (OP4.01, BP 4.01, GP 4.01)

This policy requires Environmental Assessment (EA) of projects proposed for Bank financing to help ensure that they are environmentally sound and sustainable, and thus to improve decision making. The EA is a process whose breadth, depth, and type of analysis depend on the nature, scale, and potential environmental impact of the proposed investment.. The EA process takes into account the natural environment (air, water, and land); human health and safety; social aspects (involuntary resettlement, indigenous peoples, and cultural property) and transboundary and global environmental aspects.

Operational Policy 4.01 further requires that the EA report must be disclosed as a separate and stand alone document by the Government of Kenya and the World Bank. . The disclosure should be both in Kenya where it can be accessed by the general public and local communities and at the InfoShop of the World Bank and the date for disclosure must precede the date for appraisal of the project.

The World Bank system assigns a project to one of three project categories, as defined below:

- ***Category "A" Projects***

  An EIA is always required for projects that are in this category. Impacts are expected to be 'adverse, sensitive, irreversible and diverse with attributes such as pollutant discharges large enough to cause degradation of air, water, or soil; large-scale physical disturbance of the site or surroundings; extraction, consumption or conversion of substantial amounts of forests and other natural resources; measurable modification of hydrological cycles; use of hazardous materials in more than incidental quantities; and involuntary displacement of people and other significant social disturbances.

- ***Category "B" Projects***

  Although an EIA is not always required, some environmental analysis is necessary. Category B projects have impacts that are 'less significant, not as sensitive, numerous, major or diverse. Few, if any, impacts are irreversible, and remedial measures can be more easily designed.' Typical projects include rehabilitation, maintenance, or upgrades, rather than new construction.

- ***Category "C" Projects***

  No EIA or other analysis is required. Category C projects result in negligible or minimal direct disturbance of the physical environment. Typical projects include education, family planning, health, and human resource development.

The Nairobi Water Sources Phase 1 project has been assigned a Category A.

Involuntary Resettlement (OP 4.12)

The objective of this policy to avoid where feasible, or minimize, exploring all viable alternative project designs, to avoid resettlement. This policy is triggered in situations

involving involuntary taking of land and involuntary restrictions of access to legally designated parks and protected areas. The policy aims to avoid involuntary resettlement to the extent feasible, or to minimize and mitigate its adverse social and economic impacts.
This policy covers direct economic and social impacts that both result from Bank-assisted investment projects, and are caused by (a) the involuntary taking of land resulting in (i) relocation or loss of shelter; (ii) loss of assets or access to assets, or (iii) loss of income sources or means of livelihood, whether or not the affected persons must move to another location; or (b) the involuntary restriction of access to legally designated parks and protected areas resulting in adverse impacts on the livelihoods of the displaced persons.
The policy prescribes compensation and other resettlement measures to achieve its objectives and requires that borrowers prepare adequate resettlement planning instruments prior to project appraisal of proposed projects. The objective of this policy to avoid where feasible, or minimize, exploring all viable alternative project designs, to avoid resettlement. The policy requires the displaced persons and their communities, and any host communities receiving them, are provided timely and relevant information, consulted on resettlement options, and offered opportunities to participate in planning, implementing, and monitoring resettlement. Appropriate and accessible grievance mechanisms are established for these groups. In new resettlement sites or host communities, infrastructure and public services are provided as necessary to improve, restore, or maintain accessibility and levels of service for the displaced persons and host communities.
This policy is triggered when a project activity causes the involuntary taking of land and other assets resulting in:

1) *Relocation or loss of shelter,*
2) *Loss of assets or access to assets,*
3) *Loss of income sources or means of livelihood, whether or not the affected persons must move to another location,*
4) *Loss of land,*

Dam Safety (OP 4.37)
This policy is triggered if the project involves construction of new dam(s), or is dependent on an existing dam, or a dam under construction. In the case of new dams, experienced and competent professionals to design and supervise construction; borrower adopts and implement dam safety measures for the design, bid tendering, construction, operation and maintenance. In the case of existing dams, any dam that can influence the performance of the project must be identified and its safety assessed. Necessary dam safety measures or remedial work are implemented. Dams over 15 metres in height are classified as large dams. High hazard dams are those under 15 metres but which are in a zone of high seismicity and /or where foundations and other design features are complex.
An independent dam safety assessment may be required prior to construction of the proposed intake weirs and the Northern Collector tunnel since the aim of the project is to increase the water intake into Thika Reservoir.

Bank Operational Policy 4.11-Physical Cultural Resources
The objective of this policy is to assist in preserving physical cultural resources (PCR) and avoiding their destruction or damage. PCR includes archaeological, paleontological, architecturally significant, and religious sites including graveyards, burial sites, and sites of unique natural value.
Initial indications are that no observed physical or cultural resources will be affected by the project. Nevertheless, the Contractor is responsible for familiarizing themselves with the

following “Chance Finds Procedures”, in case culturally valuable materials are uncovered during excavation, including:

1. Stop work immediately following the discovery of any materials with possible archeological, historical, paleontological, or other cultural value, announce findings to project manager and notify relevant authorities;
2. Protect artifacts as well as possible using plastic covers, and implement measures to stabilize the area, if necessary, to properly protect artifacts
3. Prevent and penalize any unauthorized access to the artifacts
4. Restart construction works only upon the authorization of the relevant authorities.

All contracts should include a Chance Finds Procedure clause.

1.4 Consultations

The objective of public consultations with stakeholders is gather information on their concerns, perceptions and fears of the livelihood changes to be brought about as a result/consequence of the project .
Public consultations will need to be organized when detailed designs and plans are available, and prior to construction, as a way to collect first-hand accounts of benefits and grievances from interested and affected parties. Consultation will involve organized group discussions with purposively selected individuals/stakeholders to gain information on their concerns, perceptions, reactions and experiences as a result/consequence of the project
A stakeholder mapping exercise will be conducted to identify all the stakeholders within and in the surrounding area including local community, local authorities, civil society, government ministries and agencies, government projects and private sector among other stakeholders.

Stakeholder Workshop
A stakeholders meeting was held on 30th August 2011, informing all stakeholders about the perceived project. The Proceedings of the Stakeholders Workshop are attached as Annex 2. Amongst the points presented were the perceived environmental impacts and their potential mitigation. Further consultations with stakeholders will be held during the preparation of the detailed EIA for which Athi Water Services Board (AWSB) are preparing the request for proposals for consultancy work.

2 Study Area

2.1 Geology

The Study Area is overlain with an ancient core of crystalline rocks of the Basement Complex which underlies the greater part of the plateau areas of Africa which have been affected by the extensive faulting, displacement and volcanic activity associated with the Rift Valley System. The eroded surface of the pre-Cambrian basement rocks outcrops only on the southern and eastern margins of the area. Elsewhere it is overlain by a variable thickness of volcanic and pyroclastic rocks of Tertiary age.

The Tertiary succession comprises various lava flows, pyroclastic rocks or their weathered derivatives, and also paleosols, developed intervening periods sub-aerial weathering. Uplifting and concentration of volcanic activity at the margins of Rift Valley has resulted in a general alignment of lava flows and associated surface deposits in a south easterly direction. The character of the volcanic events both in space and time has dictated the lateral and vertical variability.

2.2 Topography and Drainage

The Tertiary volcanic uplands on the edge of the Rift Valley forms the source of the present drainage network. The highest land occurs in the Aberdare Mountain Range where elevations of over 3,500 metres are reached within the Study Area. From the vicinity of Mt. Kinangop, the highest point, rise four major tributaries of the River Tana; the most Southerly, the River Chania, which provides the greater part of Nairobi's present water supply, and the Rivers Thika, Maragua and Mathioya.

The rivers within both the Tana and Athi drainage basins form a parallel series, largely oriented in a south-easterly direction, following the dip of the underlying lava flows. They form deeply incised valleys in long narrow catchments with steep slopes. There is generally a thick mantle of weathered rock and soil and bedrock is rarely exposed except within the river channel. This weathered mantle and the forest vegetation which covers elevations above 2,200 metres dampen the flood response of the rivers to intense rainfall and also sustain dry weather flows. The rivers emerge from these incised valleys onto a flat piedmont zone at an elevation of approximately 1500 metres, without significant perennial tributaries, and join the main Athi and Tana Rivers.

South of Nairobi, with exception of the Ngong Hills which rise to 2460 metres, the character of the landscape changes. The headwaters on the Rift Valley margin are both flatter and lower in elevation and in their middle courses the widely spaced tributaries of the Athi flow through a rolling plateau, with occasionally rocky hills standing above the general level. Downstream, the course of the Athi approaches that of the lower Thika River and at one point they are separated by a distance of only 1.5 km with an intervening relief of 50 metres. Subsequently their courses diverge, the Thika turning northwards to join the Tana at Masinga Reservoir and the Athi continuing South eastwards along the margin of the Yatta plateau.

The rivers of interest to this study rise in the moorlands and forests of the Aberdare Mountain Range. The highest peak in the southern Aberdares is Kinangop Peak, at 3,906 masl. The upper drainage is within the National Park and comprises undulating moorland with swamps and patches of Hagenia woodland and Ericaceous heath. The Eastern Aberdare Rivers formed within the high altitude moorland, flow eastwards into deeply incised forest-clad valleys within the Forest Reserve surrounding the National Park. The upper forest zone is typically bamboo, changing to forest in the lower slopes. The Forest Reserve boundary, at about 2,200 masl, is demarcated by an electric fence, 420 km long, which surrounds the Aberdare Conservation Area (this is now the longest electrified game-proof fence in Africa). Below the Forest Reserve boundary of the Eastern Aberdares lies a zone of smallholder tea plantations on the slopes of the deeply incised valleys. Details of the hydrology of this area are presented in the Water Sources Options Review Report (August 2011).

The forested catchment area is protected, as it lies within the National Park and adjacent Forest Reserve. These forests play an important role in maintaining dry season flow by stabilizing the soils, maintaining infiltration rates and reducing wet season water runoff. The importance of the forests to the catchment hydrology has long been recognised, and the Government is committed to forest conservation.

The perennial streams flowing from the eastern Aberdares not only provide domestic supplies for a densely populated smallholder farming area, but are also the source of dry season irrigation for Kenya's major coffee and pineapple plantations, as well as other irrigated areas such as those supplied by the Yatta Furrow. In addition, these streams provide water supplies for the city of Nairobi, support hydropower production, and also help to maintain the flow of the two major rivers in Eastern Kenya, the Tana and Athi, on which the people of these drier areas depend.

Demand for water has been increasing because of increases in population and growing needs for irrigated agriculture, urban and rural populations, industries, livestock, and hydropower. There is concern[1] that water sources in the country are degraded as a result of: excessive abstraction of surface waters and groundwater; soil erosion and resultant turbidity and siltation, high nutrient levels, causing eutrophication of water bodies; as well as toxic chemicals, including agricultural pesticides and heavy metals.

2.3 Climate

The climate of the area is predominantly controlled by its equatorial position, the continent's large scale pressure systems and the Indian Ocean. However, topography strongly influences the magnitude of the climatic elements and to a lesser extent their seasonal distribution.

The seasonal distribution of rainfall is dominated by the movement of the Inter Tropical Convergence Zone (ITCZ) which separates the North eastern and South eastern trade wind systems and the belt of maximum rainfall follows the position of the overhead sun with a time lag of about 4 to 6 weeks. The two rainy seasons are therefore centred around April-May (Long Rains) and October-November (Short Rains). During the intervening dry seasons monsoonal systems bring rather dry air masses. From December to March the persistent North easterly monsoon brings clear sunny weather with only occasional showers. During the period of South easterly monsoon from June to October the weather is duller and cooler with occasional drizzle which is more persistent at higher elevations.

The highest annual rainfall totals of over 2,600 mm occur on the windward side of the summit of the Aberdares and there is a decline with elevation which is more rapid on the leeward slope towards the Rift Valley than on the windward side. Further south in the headwaters of the Thiririka and Ruiru rivers the rainfall divide is towards the east of the topographic divide. There is also a decreasing rainfall towards the South.

At the edge of the piedmont zone between Nairobi and Thika, the annual rainfall declines to between 800 – 900 mm. To the South within the Upper Athi catchment there is a further

[1] Summary Environmental Social Impact Assessment, Small Towns Rural Water Supply and Sanitation Project, Kenya 2009. ADB.

reduction to less than 600 mm. These areas of lower rainfall also have a higher coefficient of variation.

Other climatic elements have a significant influence on water resources, especially in their effect on the rate of evapotranspiration loss. Throughout the area mean daily temperature varies little with season and the diurnal variation is generally greater than the seasonal variation. With increasing altitude, daily minimum temperature values decrease more rapidly than the daily maximum. Typically the annual average diurnal range at elevations of 1,500 metres is 13°C to 25°C whilst at 2,500 metres the range is from 6°C to 22°C.

Mean annual relative humidity values range from 65% at lower elevations to 80% or more above 2,500 metres. Humidity is greatest at dawn and lowest in the early afternoon when the temperature reaches the diurnal maximum.

Below 1,500 metres the mean daily duration of bright sunshine ranges from 4 hours during July and August to 9 hours during the Northern Monsoon season with an annual mean of 6.8 hours. Sunshine decreases with altitude, with an annual mean of 5 hours at 2,500 metres.

Mean annual free water surface evaporation as calculated by Woodhead ranges from around 1,800 mm in the piedmont zone to less than 1,400 mm in the Aberdares Range. Potential evapotranspiration is estimated to be about 75% of free water evaporation in the highlands and 80% or more in dryer areas.

2.4 Groundwater Resources

The Report on Review of Groundwater Resources (June 2011) discusses the groundwater exchange with rivers and concludes that a significant part of the aquifer outflows by drainage to the rivers. This water forms the river base flow, and it is estimated that the Nairobi Groundwater Body (NGWB) contributes an estimated 335 MCM/year to the rivers. Contribution of the rivers to recharge of the aquifer should also be considered. Where important abstraction occurs (e.g. beneath Nairobi City), local water depletion is observed. In these sectors, the rivers are not draining the aquifer but contribute to the recharge at an estimated rate of 17 MCM/year for the NGWB area.

3 Development of Groundwater Well Fields

The availability of potential groundwater resources was presented in the report on Review of Groundwater Resources (June 2011). Although an investigation program and exploratory drilling is required in order to locate suitable high yielding formations and to give precise estimation of the well-fields' potential and to confirm the availability and suitability of this resource, significant use of this groundwater resource as part of the Nairobi water supply is expected.

3.1 Potential Groundwater Well Fields

Preliminary investigations suggested a first selection of potential sites within the Nairobi Groundwater Body (NGWB), targeting the large yielding potential areas upstream from the main cities' pollution, and identified the basalt outcrops in the Kiunyu sector (Figure 3-1Figure 3-1). It was also suggested that untapped aquifers could include deep Athi series sediments located to the west and north-west of Nairobi, with the advantage of being up-gradient of Nairobi City and also being closer to higher rainfall areas and sources of groundwater recharge. A potential site was identified to the North of Kiambu, northwest of Ruiru area (Figure 3-2Figure 3-2).

The Review of Groundwater Resources report has indicated that each groundwater development site is most likely to consist of well-fields producing a minimum of 30,000 m^3/day each. Furthermore, due to operational constraints, each of these the well-fields should not consist of more than 20 boreholes, i.e. each borehole should be able to produce some 60 m^3/h or more.

In the absence of detailed plans, a full environmental assessment is not feasible. However, a scoping of potential impacts from the potential development of these well fields and associated distribution pipelines is presented below.

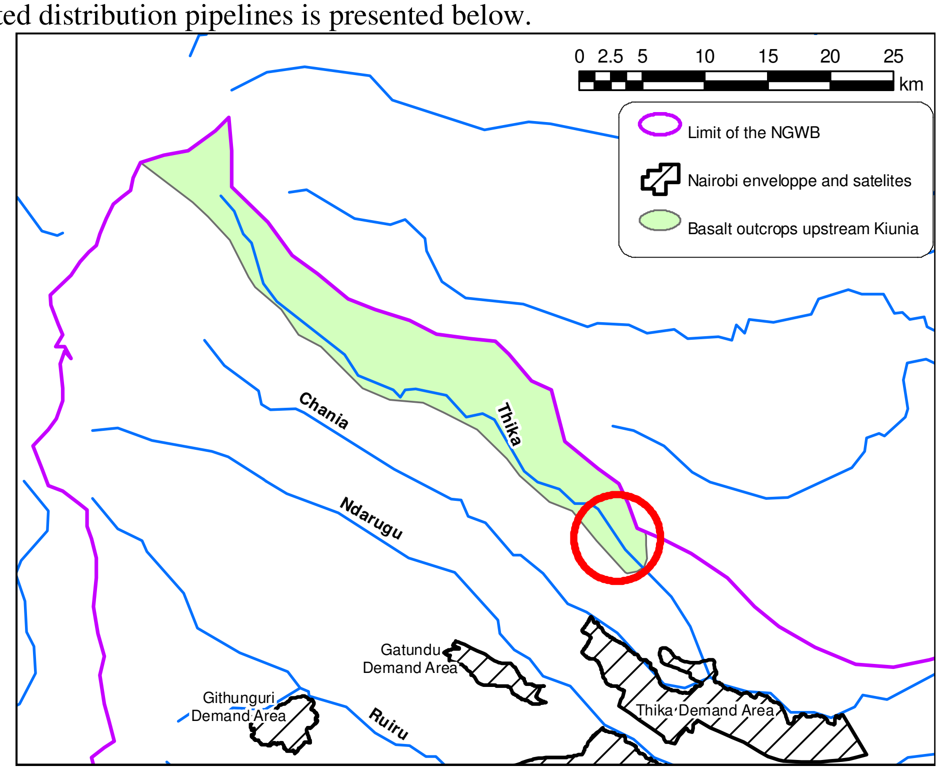


Figure 3-1. Possible location (red circle) of a 35,000 m3/day well-field in Kiunyu sector, near the Thika River.

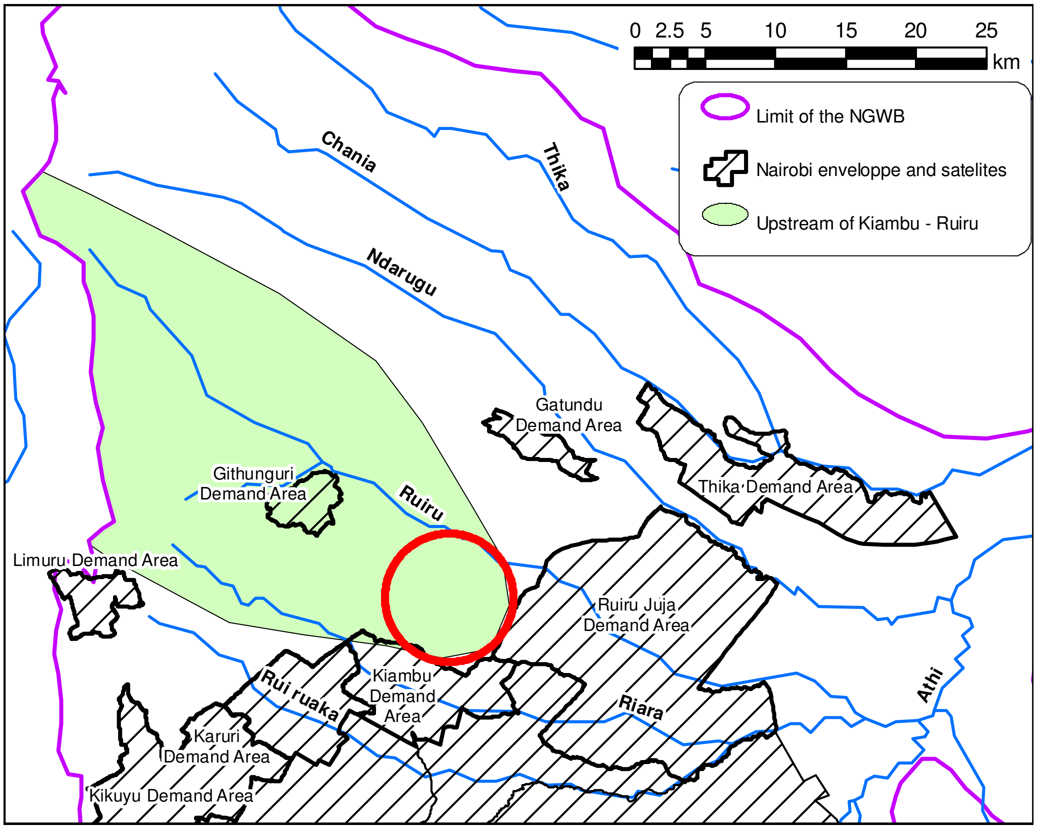


Figure 3-2. Possible location (red circle) of a 30,000 m^3/day well-field in the north of Kiambu - NW of Ruiru area.

3.2 Scoping of Potential Impacts

An increase in the abstraction of groundwater resources from the Nairobi Groundwater Body is likely to have a negative impact on the contribution of the aquifers to the base flow in rivers draining this area.

3.2.1 Preliminary Exploration

An investigation program and exploratory drilling is required in order to locate suitable high yielding formations and to give precise estimation of the well-fields' potential and to confirm the availability and suitability of this resource. The exploratory drilling is then expected to identify the optimum locations for drilling and installation of new productive well-fields. This exploratory drilling will result in local level disturbance at each of the sites where exploratory drilling takes place. The proposed areas for investigation are primarily agricultural and it is expected that this disturbance will result in loss of earnings for the affected users of the land at each exploratory site. The loss of agricultural earnings will to a large extent be determined by the type of crops grown at individual sites. Drilling in areas dominated by coffee will, for example, result in medium-term damage and loss of earnings until replacement coffee trees become productive. On the other hand, exploratory drilling in areas with an annual crop will result in short-term impacts and loss of earnings.
In addition, it is also expected that exploratory drilling will result in changes to the land cover, e.g. through loss of tree cover and loss of other vegetation, potential loss of crops, and

disturbance to the soil which may result in longer term changes to productivity. This loss of earnings will require compensation.

Exploratory drilling may also impact on streams and rivers directly. There is the potential for contamination from drilling activities draining directly into wetlands unless preventative measures are implemented.

Potential Impacts include:

1. Changes in groundwater contribution to base flows in rivers, and reduction in local water supplies available from springs and dug wells.
2. Degradation of Aquifers.
3. Loss of Vegetation and Impacts on Agricultural Land.
4. Impacts from Drilling Activities themselves.
5. Noise Impacts.
6. Accidental Spillage.

1. Impacts on Base Flows in Rivers, and on Springs and Dug Wells

Groundwater resources are generally responsible for maintenance of a proportion of base flows in streams and rivers. In the case of the Nairobi Groundwater Body, it is not known to what extent natural groundwater discharge maintains springs and stream base flows, and thus what will be the environmental impact of increased groundwater abstraction.

In addition, as a result of increased abstraction of groundwater resources from specific strata there are likely to be impacts on local water supplies to households and communities that use springs or dug wells.

Mitigation

- It will be necessary to install an increased network of river gauges and recording stations in order to cover the potentially impacted areas. Regular, daily monitoring and reporting of these river gauges will be necessary.
- At times when reduced base flows are considered to have occurred, or are likely, and where these fall below accepted Reserve Flow limits, it will be necessary to supply an increased flow from upstream resources in order to compensate for the reduced flow and to ensure adequate downstream environmental flows, as well as sufficient flow for communities reliant on these resources (compensation flows). It may also be necessary to reduce the levels of groundwater abstraction.
- All existing springs and dug water supply wells in the areas within the geological strata affected by the proposed groundwater well fields will need to be identified and mapped. The yields from these sources will need to be recorded and monitored. Alternative, piped, water supplies will need to be provided in those cases where these water sources are impacted by reduced groundwater levels resulting from abstraction.

2. Degradation of Aquifers

The present groundwater contribution to Nairobi water supply is limited and groundwater development is still considered to be possible.

According to the Review of Groundwater Resources (June 2011) it is considered that the groundwater abstraction can be increased by 2 or 3 times. However, since it is not known to what extent natural groundwater discharge currently maintains base flows, the impact of increased groundwater abstraction on base flows is uncertain. Such

impacts are possible and, as indicated above, flows will need to be carefully monitored in order that impacts related to reduced base flows can be addressed by suitable mitigation measures.
Aquifers are vulnerable to degradation during and following exploratory drilling in the following ways:

- Aquifers may be contaminated by entry through open boreholes by run-off water from the surface, such as in saline and industrial areas.
- Aquifers containing useable-quality water may potentially be connected by drill holes to aquifers with inferior-quality water or to leakage zones. Cross flow may be induced by natural pressure differences or pressure differentials induced by pumping.
- Uncontrolled flow of pressure aquifer water through drill holes between aquifers of different quality water or through uncontrolled flow to wastage at the surface.

Contaminated groundwater aquifers and wetland water regimes have the potential to affect the habitat and diversity of the aquatic flora and fauna. Groundwater aquifer contamination may potentially be result, as some streams and rivers may be fed by groundwater.
Reuse of treated wastewater through artificial recharge of aquifers is seen an efficient alternative method for effluent disposal. This is especially pertinent, given localized declining groundwater levels beneath Nairobi (Review of Groundwater Resources, June 2011). However, as the groundwater resource is increasingly widely exploited, such injected water will be abstracted relatively soon after injection and the natural purifying behaviour of the aquifer should not be taken into account. Primary, secondary and advanced treatment will be necessary to make its quality acceptable for direct injection into the groundwater system.

Mitigation

- Careful attention should be given to ensure that the well is fully cased as it passes through the water table; and
- Ensure that all required safety measures are in place and that staff are aware of procedures that reduce potential contamination of groundwater.
- In order to limit the impact on the groundwater levels, the groundwater development should be located close to the rivers. According to the Review of Groundwater Resources (June 2011) a potential of some 75,000 m^3/day should be available in these sectors. The best sectors for such groundwater development will be identified once exploratory groundwater prospecting is conducted.
- In the other sectors, where groundwater abstraction for public water supply already exists, this abstraction can be increased without major problems. The exact location for such additional boreholes should be set up after further hydro-geological prospection in order to limit the local drawdown, and potential negative impacts on the groundwater resource.
- The Water Act has general guidelines on protection of water sources against pollution. However, it does not set specific protection zones around public water supply wells. The definition of such zone is now viewed as a necessity, as well as an immediate protection of the area surrounding each well to prevent any accidental chemical or bacteriological pollution of groundwater resources.

3. Loss of Vegetation and Impacts on Agricultural Land

Potential vegetation loss will result from building and establishment of necessary infrastructure, from drilling activities themselves and from construction of new access tracks, or modification to existing tracks.

Site establishment would result in an increase in dust due to vegetation clearing and vehicles and trucks driving to and from the site along farm dirt roads. Limited dust would be generated by the actual drilling activities. However, it is considered that dust generation would be minor and would be of a very short duration and the significance of this impact is considered to be low.

The total footprint of vegetation to be affected would be approximately 50 m x 50 m per drilling site, as well as the area of the access road. As far as possible existing access roads must be used in order to limit the construction of new access tracks.

Mitigation

- Ensure that only the necessary vegetation cover is removed to reduce the amount of exposed bare ground.
- Demarcate the site camp and access road prior to any vegetation clearing.
- Ensure that only vegetation within this designated area (and the access road) is impacted on.
- Remove only the necessary vegetation during site establishment.
- Any topsoil removed should be stockpiled and replaced during rehabilitation.
- Rehabilitate all disturbed areas on completion of the drilling activities.

4. Impacts from Drilling Activities

Earthen Pits or Drilling Sumps, also known as Reserve Pits, excavated adjacent to drilling rigs are commonly used and set aside for the disposal of drilling muds and other material used in the drilling process. Drilling Sumps can contaminate soil, groundwater, and surface water with metals and hydrocarbons if not managed and closed properly.

Mitigation

- Drilling mud should not be disposed of in any area where it can potentially enter and contaminate the drainage system.
- Where topsoil has to be removed it should be stored nearby in low mounds together with any plant litter. Topsoil should be returned as soon as possible (preferably within 6 months) to maintain seed viability and microbial activity. If drilling sumps are required then soil and sub-soil should be stockpiled separately and replaced in the reverse order to its excavation.

5. Noise Impacts

The proposed drilling operations would result in a constant noise generation from drilling and would include noise from vehicles and trucks driving to and from the site. During site establishment, large trucks and vehicles would drive to and from the site, while during drilling operations, staff would move about to and from work. The potential noise impacts would be at the local level, of high intensity and short term.

Mitigation

- Liaise with the surrounding landowners and should they feel the noise is significant, drilling **activities should not occur at night.**

6. Accidental Spillage

During storage and transfer of oil and diesel for drilling operations, there is a potential for an accidental spill onto open ground. Diesel and oil would be required during drilling. Diesel and oil drums would be transported to and stored on site. During the transfer of these drums, there is potential for an accidental spill onto the natural ground. The potential impact of an oil / diesel spill on the surrounding environment would be at the local level, is considered to be of high intensity and short term.

Mitigation

- Ensure that all diesel and oil drums are stored in a fully bunded area.
- Ensure that the transfer of diesel and oil from drums occurs in the fully demarcated and bunded area, otherwise drip trays must be used.
- Ensure that all staff are aware of procedures to be followed for dealing with spills and leaks.
- Ensure that spills are immediately removed along with all contaminated material and disposed of at an approved site for disposal of hazardous material.
- Ensure that all contaminated material is stored in a bunded area before being disposed of.
- Ensure that suitable spill kits are available on site, to be applied to all contaminated areas that will absorb or breakdown the spills. The quantity of such materials shall be able to handle the total volume of the hydrocarbons stored on site.

3.2.2 Development of New Well Fields and Increased Extraction from existing Well Fields

The development of new well fields at sites confirmed by the exploratory drilling will have initial impacts similar to those listed above from exploratory drilling. The same measures for mitigation and prevention of negative impacts will need to be followed. However, it is expected that the size of the areas impacted will be greater in order to accommodate the required number of groundwater wells.

Longer term impacts will subsequently result from the operation of each of the well sites together with associated transmission and distribution pipelines. This will include:

- Compensation for loss of land.
- Compensation for loss of agricultural production and livelihoods.
- Operation of the pipeline wayleave in private land.
- Impacts resulting from potential pipeline leakage.

4 Development of the Northern Collector Tunnel, Phase 1

Phase 2 of the selected scenario for development of water sources for Nairobi includes the development of the **Northern Collector Tunnel Phase I. This will enable the abstraction and diversion of water from Maragua, Gikigie and Irati Rivers to Thika reservoir. Implementation is planned by** 2016. This will be followed in the next phase by the subsequent development of the Northern Collector Tunnel Phase 2, diverting water from the South Mathioya, Hembe, Githugi and North Mathioya Rivers, by development of the Northern Collector Tunnel, Phase 2. This will also flow though the Northern **Collector Phase I Tunnel.**

The Northern Collector Phase 1 comprises an 11.4 km long Tunnel, with weirs and intake structures on the Maragua, Gikigie and Irati Rivers, the Irati shaft, and Makomboki Outfall. From the outfall, the flow from the Northern Collector Tunnel will be conveyed to Thika Reservoir. These are detailed in **Table 4-1**~~Table 4-1~~. There will also be the construction of a **Raw Water Gravity Main to Ngorongo Treatment Works, the development of the Ngorongo treatment works, and the construction of a Treated Water Gravity Main to Kabete Reservoir.**

The main environmental and socioeconomic impacts resulting from the Northern Collector Tunnel Phase 1 will be related to the diversion of water, and the resulting significant reduction in downstream flows in these rivers. This requires the assessment of the required downstream Reserve Flows, including both Environmental Flows and Compensation Flows. Such impacts are expected to be long-term. Additional impacts are related to the construction of the facilities themselves, and these are expected to be local-level and relatively short-term impacts.

Table 4-1: Northern Collector Phase 1 Components

A: Northern Collector Tunnel

Tunnel	• 11,4 km long tunnel • Finished internal diameter: 3,20 m • Slope: 0,16% to 0,19% • Lined with concrete
Maragua weir	• Mass concrete weir across Maragua River, with retaining walls. • About 18.50 m wide • Elevation about 4.75 m above bed level. • Protection of river slopes with gabions and grass/tree plantation
Maragua intake	• Stilling basin • Control weirs • Compensation channel to release flow to the river • Portal of tunnel
Gikigie weir	• Mass concrete weir across Gikigie River, with retaining walls • About 10 m wide • Elevation about 3.90 above bed level • Protection of river slopes with gabions and grass/tree plantation.
Gikigie intake	• Stilling basin • Control weirs • Compensation channel to release flow to the river • Portal of adit

Gikigie access adit	• Length : about 145 m • Section : internal diameter: 3,20 m (same as tunnel) • Slope: about 4.4%
Irati weir	• Mass concrete weir across Irati River, with retaining walls. • About 14.5 m wide • Elevation about 0.90 above bed level • Protection of river slopes with gabions and grass/tree plantation
Irati intake	• Stilling basin • Control weirs • Compensation channel to release flow to the river • Connection to Irati shaft
Irati shaft	• Depth : 46m • Diameter: 4 m (finished internal diameter) • Vertical shaft • Lined with concrete
Irati shaft connection to tunnel	• Connection between shaft and tunnel. • Same diameter as tunnel (3.20 m)
Kaanja access adit	Such an access adit would enable driving the tunnel on up to 6 faces. Exact length of such construction adit (tentative length is 150 m) as well as access tracks require additional detailed studies at construction stage.
Makomboki outfall	Outfall nearby Makomboki village will include: • Portal of downstream end of tunnel • Concrete channel with falls (total fall is about 5 m) and retaining walls. • Grouted stone pitching • Protection of river slopes with gabions and grass/tree plantation

B: Transmision Line from Thika second offtake to Ngorongo High Level Water Treatment Works

Raw water gravity main from Thika dam second outlet to Ngorongo Treatment Works	• Length: 42 km • Steel pipe

C: Ngorongo High Level Water Treatment Works and Treated Water Gravity Main

Ngorongo Water Treatment Works	
Treated water gravity main from Ngrongo WTW to Kabete reservoir	• Length: 17 km • Steel pipe

5 Downstream Reserve Flows

The planned abstraction of water from rivers flowing from the Aberdares to provide new water sources for Nairobi, will inevitably have significant impacts on flows downstream of the intake sites. Modifications made to river flows need to be balanced with the maintenance of ecological services that depend on the stream flow and flow regime. Resources required to maintain these services are termed "Environmental Flows". The Kenya Water Act (2002) reinforces the principle of maintaining environmental flows in river systems and calls for a "Reserve" to be set for all rivers and to be considered in all water allocation plans. The Reserve for a given river is considered to be the level of instream flows necessary to provide for basic domestic use as well as to sustain the river ecosystem. The Reserve is defined as "that quantity and quality of water required (a) to satisfy basic human needs for all people who are or may be supplied from the water resource; and (b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the water resource."

Reserve Flows therefore includes the requirements for both *Compensation Flows* and *Environmental Flows*.

Compensation flows are those that are set for purposes such as downstream human uses, including household and domestic use, livestock, irrigation, sewage treatment, hydropower, and industrial use. Environmental flows are distinct from Compensation Flows and the two flows need to be evaluated separately, although they can only be released as the combined Reserve Flow.

Environmental flow management provides the water flows needed to sustain freshwater ecosystems in coexistence with agriculture, industry, and urban areas. Reduced flows will have impacts on downstream environments through changes to water flow patterns (the flow regime), as well as the quantity and quality of the available water. There will also be impacts on all downstream communities that depend on the water resources in the impacted rivers.

It is recognised that stream flow, and the flow regime, is strongly related to many critical physiochemical components of rivers, such as dissolved oxygen, channel geomorphology, water quality, and habitats. Stream flow is also considered as "master variable" that determines or limits the distribution, abundance, and diversity of many aquatic plant and animal species.

5.1 Environmental Flows

Environmental flows provide the flow regime required for maintaining downstream river ecosystems in a desired state, and for maintaining riverine ecosystems and their benefits. Natural flow variability is one of the most important components of any healthy river. It is not only the amount of water in a stream, but its variability that supports species, habitats, and environmental processes. Earlier efforts at defining in-stream flow requirements led to the development and setting of minimum flows. Application of these methods usually resulted in a single fixed minimum flow value, below which water may not be withdrawn for consumptive use.

In practice these minimum flow values are almost always less than optimal. There is a growing international consensus (Hirji and Lintner, 2010)[2] that environmental flows should

[2] Rafik Hirji and Stephen F. Lintner (2010) Environmental Flow Assessments to Conserve Aquatic Ecosystems: World Bank Experience. Washington, DC: The World Bank.

be described in terms of seasonal low flows, as well as the magnitude, timing and duration of flood events. It is the flow regime that is important, rather than a fixed minimum flow. A full range of natural hydrologic regimes is considered as an essential element for sustaining the riverine environment. It is now also recognised by water resources scientists that *Minimum Flow Standards tend to provide Minimum Protection*.

Four guiding principles about the influence of flow regimes on aquatic biodiversity are recognised.

- *Principle 1:* Flow is a major determinant of physical habitat in streams, which in turn is a major determinant of biological composition.
- *Principle 2*: Aquatic species have evolved life history strategies primarily in direct response to the natural flow regimes.
- *Principle 3*: Maintenance of natural patterns of longitudinal and lateral connectivity is essential to the viability of populations of many riverine species.
- *Principle 4*: Alteration of flow regimes is likely to facilitate the invasion and success of exotic and introduced species in rivers. Increase in exotic species is likely to have a negative impact on indigenous species.

The presence of adequate high and low flow pulses is an important indicator of the health of an aquatic community. A single, minimum, threshold flow, with the exclusion of other ecologically relevant flows, is no longer a scientifically accepted approach to instream flow management. “Flatlining” is a descriptive term that illustrates the removal of the flow variation in a river, thereby reducing it to a low, constant flow, essentially a permanent drought flow. By removing variability in stream flow, aquatic habitats and water quality are degraded. Reduced flows, and the reduced variability of flow, also affect a stream’s ability to provide a range of ecosystem services, including the ability to assimilate pollutants. Ecosystem services are defined as a variety of culturally and socially valued goods and services that human society derives from natural ecosystems. The important ecosystem services provided by rivers are disrupted by changes in the volume, quality, and pattern of flows downstream of development activities. It is now recognised that subjecting an environment to constant low flow conditions, will have inevitable negative consequences for all downstream environments and users dependant on these systems, resulting in reduced availability of water, deterioration of habitats, significant loss of aquatic life, both plant and animal, and in reduced ecosystem services such as regulation of water quality.

Water management problem solving has now matured from the setting of fixed minimum flows to a recognition of the need to set incremental methods in which the requirement of aquatic habitats are quantified as a function of discharge.

In the absence of detailed long-term ecological studies (which often tend to focus only on individual species) the widely used index for determining minimum Environmental Flow Release (EFR) requirements is the index of natural low flow, Q_{95}. However, release of a constant Q_{95} flow is equivalent to a constant extreme low flow – similar to a constant drought flow. Q_{95} flows are therefore seen as the minimum flow, beyond which abstraction must not occur, and it is strongly recommended that environmental flows should not be defined as constant releases but should be variable in a manner that is similar to the natural hydrograph on a seasonal basis.

Inevitably, in relatively dry periods, for example 1975 – 1976, dry season natural flows may at times be less than the required downstream environmental flow and compensation flow release. Under such conditions abstraction at intake sites should not be allowed. This is illustrated by flows from the Irati River where parts of the dry season flow were below Q_{95}

flow levels and the wet season flows were also relatively low, for much of the period remaining below 1 m^3/s (see Figure 5-1~~Figure 5-1~~).

In contrast during normal or relatively wet periods, for example 1997-1998, almost all daily flows can be expected to be greater than the Q_{95} flow, including for much of the dry season. Under these circumstances significant downstream flows should be possible during the wet seasons after all diversions and extractions have been accounted for (Figure 5-2~~Figure 5-2~~).

These examples from the Irati River illustrate the seasonal nature of natural flows to which all riverine and riparian environments are adapted. They also illustrate how the release of only Q_{95} flows as downstream environmental flows would be similar to long-term drought conditions.

If the release of environmental flows is limited to only Q_{95} flows, without supplementary higher flows, there will be unacceptable negative environmental impacts downstream of the intakes along the Northern Collector tunnel.

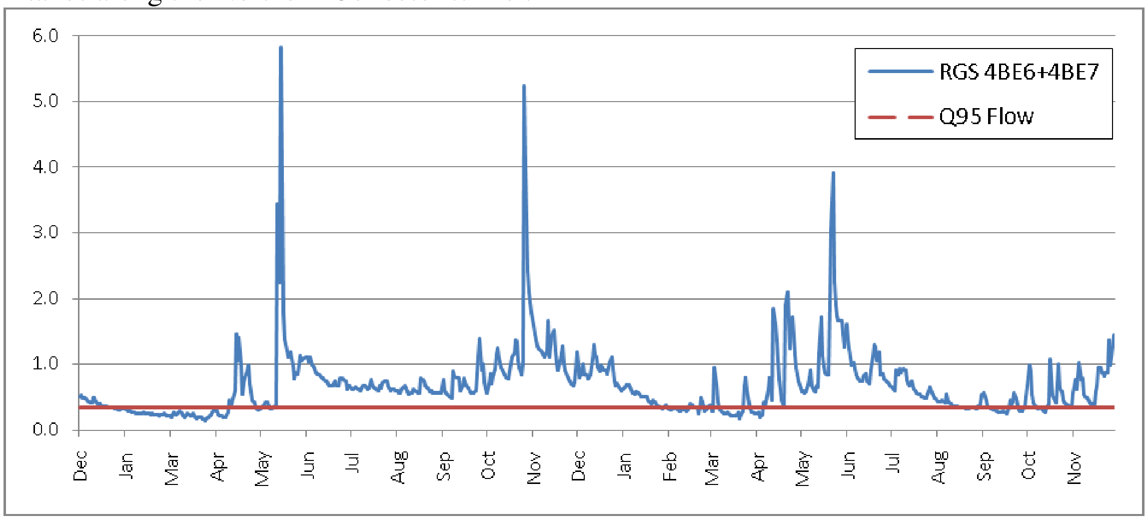


Figure 5-1: Example of flows during a relatively dry period - Irati River 1975-1976
(RGS 4BE6 and 4BE7 combined flows m3/sec)

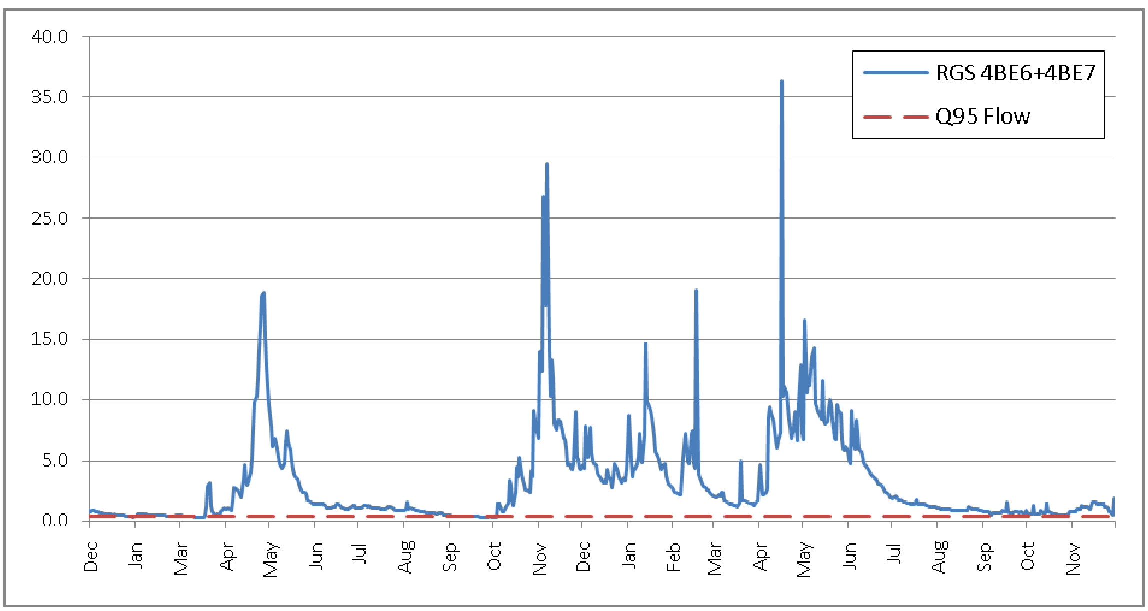


Figure 5-2: Example of flows during a relatively wet period - Irati River 1997 - 1998
(RGS 4BE6 and 4BE7 combined flows)

5.2 Environmental Flow Characteristics

Flows recorded at each of the river gauges were divided into repeating sets of hydrological patterns that are ecologically relevant, based on naturalised flow data series for the years 1950-2010. It is the full series of flow conditions represented by the principal types of flow events that must be maintained in order to sustain riverine ecological integrity, and the maintenance of downstream environments. Not only is it essential to maintain adequate flows during low flow periods, but higher flow pulses and floods also perform important and vital ecological functions.

The range and variability of a flow regime is commonly characterized by the magnitude, frequency, duration, timing, and rate of change of hydrologic events. The dominant and most important flow category is the low flow (or base flow) which, considered on a monthly basis, gives the river its dominant characteristics. The underlying assumption is that, if an ecosystem exists under the dominant baseline conditions, then any significant long-term departure from the baseline will affect the ecosystem significantly. Characteristic Environmental Flow Components (EFC) for rivers along the Northern Collector Phase 1 are presented in Figure 5-3Figure 5-3 to Figure 5-10Figure 5-10 and Table 5-3Table 5-3 to Table 5-5Table 5-5, as recorded at the river gauges and using the normalised 1950 – 2010 time series of flow data. These are considered to be the characteristic flows to which downstream environments are adapted. The flows can be divided into the following recognised flow components. The characteristics of each flow component and major influences on ecosystems are outlined in Table 5-1Table 5-1 and Table 5-2Table 5-2.

1. **Extreme Low Flows, (also known as Subsistence Flows)**
2. **Low flows, (also known as Base flows)**
3. **High flow pulses**
4. **Small floods**
5. **Large Floods**

Table 5-1: Common Characteristics for each Flow Component for different disciplines

Component	Hydrology	Geomorphology	Biology	Water Quality
Extreme Low Flows, or Subsistence Flows	Infrequent, low flows	Increased deposition of fine & organic particles	Restricted aquatic habitat. Limited connectivity	Elevated temperature Reduced levels of dissolved oxygen Reduced water quality
Low flows, or Base flows	Normal flow conditions with variability	Maintain soil moisture & groundwater table Maintain diversity of habitats	Suitable aquatic habitat. Connectivity along river channel corridor	Maintains suitable in-channel water quality

<table>
<tr>
<td>High flow pulses</td>
<td>In-channel, short duration, high flows</td>
<td>Maintain channel & substrate characteristics
Prevent encroachment of riparian vegetation</td>
<td>Recruitment events for aquatic organisms.
Connectivity to near-channel water bodies</td>
<td rowspan="2">Restore in-channel water quality after low- or extreme low flow</td>
</tr>
<tr>
<td>Small and Large Floods</td>
<td>Infrequent, high flows that may exceed the normal channel</td>
<td>Lateral channel Movement
New habitat Construction
Flush organic material into channel</td>
<td>Life phase cues for aquatic and riparian organisms.
Riparian recruitment & maintenance</td>
</tr>
</table>

Table 5-2: Environmental Influences of Different Flow Components

Flow Component	Ecosystem Influences
Extreme low flows *(initial low flow below 10% of daily flows for the period)*	• Stress and mortality due to water chemistry, temperature, and dissolved oxygen availability, but may concentrate prey in limited areas to benefit some predators, • Enable recruitment of certain floodplain and riparian plant species, • Helps to purge some invasive, introduced species from aquatic and riparian communities.
Low flows or Monthly low flows *This is the dominant flow condition*	• Provide adequate habitat for aquatic organisms, including feeding and breeding, • Maintain suitable water temperatures, dissolved oxygen, and water chemistry, • Maintain water tables in riparian zone and floodplains, soil moisture for plants , • Provide water suitable for household use, and for animals including livestock, • Enable fish and other aquatic organisms to move to feeding and breeding areas,
High flow pulses	• Shapes physical character of river channel, including pools, riffles, • Determines size and distribution of streambed (sand, gravel, stones), • Prevents riparian vegetation from encroaching into channel, • Restores normal water quality conditions after prolonged low flows, flushing away waste products and pollutants, • Prevents siltation, • Flushes and controls some pests, including mosquito larvae, bilharzia, and liver fluke.
Small floods	• Provide migration and spawning cues for fish, and enable fish to breed, • Trigger new phase in life cycle (e.g. insects), • Provide new feeding opportunities for fish, waterfowl, and other aquatic species, • Recharge floodplain and riparian water table, • Maintain diversity in riparian forest types through inundation (different plant species have different tolerances), • Control distribution and abundance of plants on floodplains, • Deposit nutrients on floodplains.
Large floods	• Maintain balance of species in aquatic and riparian communities, • Create sites for recruitment of colonizing plants, • Shape physical habitats. Deposit gravel and stones. Drive lateral movement of river channel, forming new habitats. Flush organic materials (food) and woody debris (habitat structures) into the channel, • Recharge floodplain and riparian water table, • Purge invasive, introduced species from aquatic and riparian communities, • Disburse seeds and fruits of riparian plants, • Provide plant seedlings with prolonged access to soil moisture.

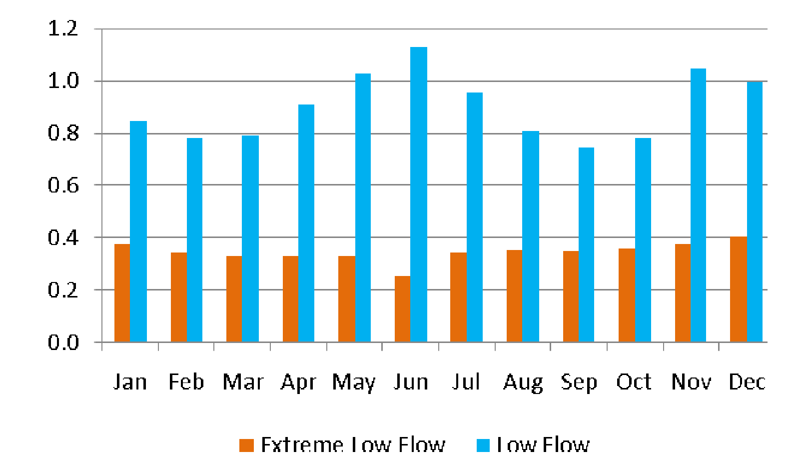
Table 5-3: Characteristic Environmental Flow Components, Irati (RGS: 4BE6+4BE7, 1950-2010)

Mean annual flow 1.71 m^3/sec Annual Coefficient of Variation 1.34
EFC high flow threshold: 1.725 m^3/sec Q95 flow 0.349 m^3/sec
EFC extreme low flow threshold: 0.422 m^3/sec Q98 flow 0.298 m3/sec
EFC small flood minimum peak flow: 11.99 m^3/sec
EFC large flood minimum peak flow: 28.61 m^3/sec

Environmental Flow Component (EFC)	Minimum (m^3/sec)	Maximum (m^3/sec)	Average (m^3/sec)	Median Flow (m^3/sec)	Frequency
Extreme low flow	**0.116**	**0.422**	**0.343**	**0.352**	**10.2%**
Low flow	**0.423**	**1.725**	**0.881**	**0.787**	**64.8%**
High flow pulse	**1.726**	**11.15**	**3.348**	**2.802**	**15.2%**
Small flood	**1.728**	**26.25**	**5.889**	**4.598**	**7.2%**
Large flood	**1.735**	**42.33**	**6.621**	**5.274**	**2.6%**

Average monthly EFC **(m^3/sec)**

	Extreme Low	Low flow
Jan	**0.377**	**0.846**
Feb	**0.344**	**0.782**
Mar	**0.330**	**0.790**
Apr	**0.332**	**0.907**
May	**0.331**	**1.028**
Jun	**0.256**	**1.126**
Jul	**0.347**	**0.953**
Aug	**0.354**	**0.807**
Sep	**0.350**	**0.747**
Oct	**0.361**	**0.782**
Nov	**0.376**	**1.045**
Dec	**0.403**	**0.995**



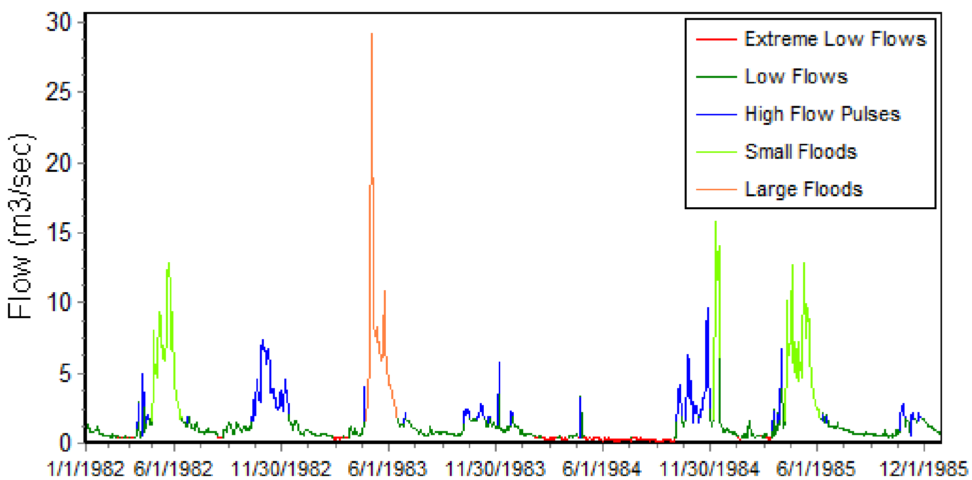


Figure 5-3: Environmental Flow Components in Irati River (RGS: 4BE6 plus 4BE7), and flows recorded 1982 – 1985, illustrating Environmental Flow Components.

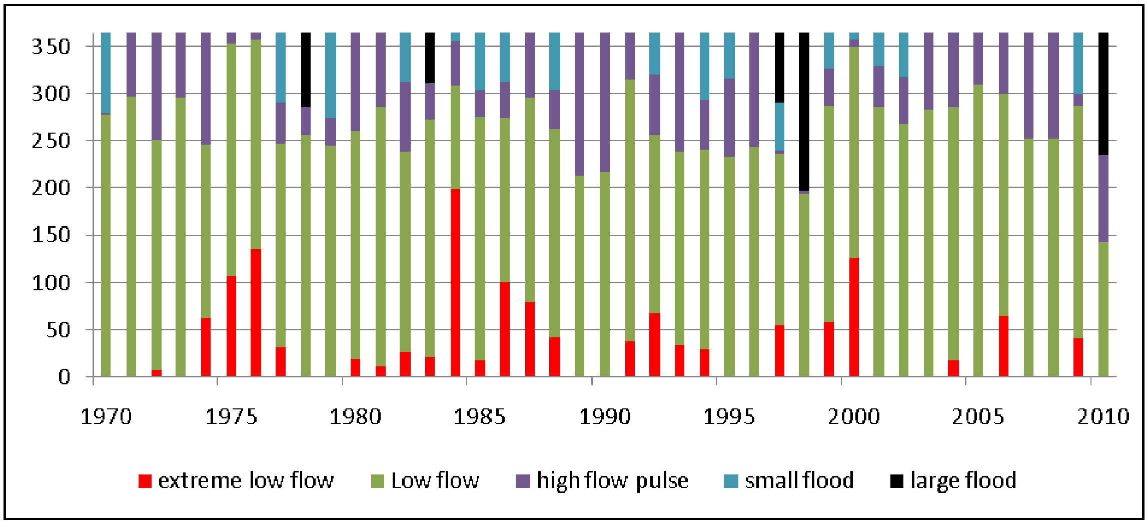


Figure 5-4: Annual Frequency of flows in each of the five EFC categories for Irati River (RGS: 4BE6 plus 4BE7), 1970-2010

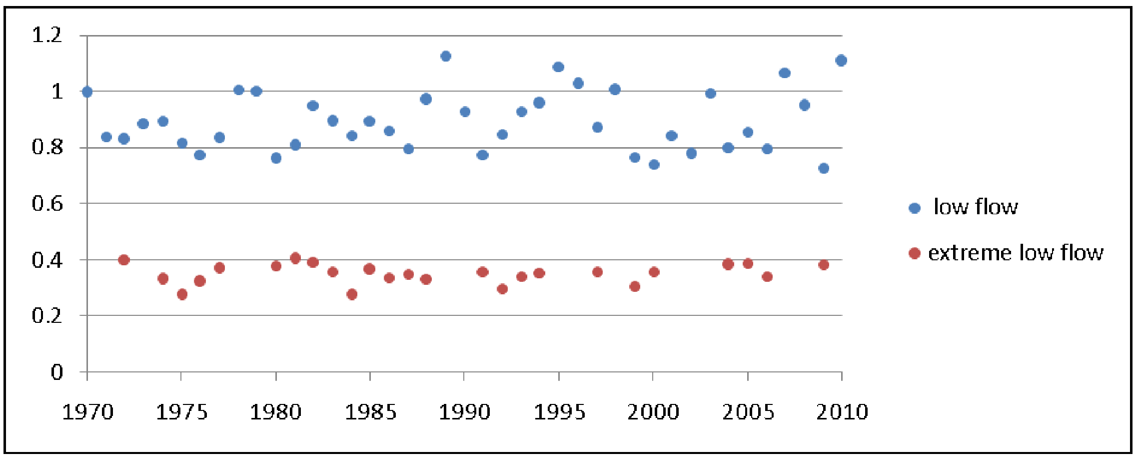


Figure 5-5: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Irati River (RGS: 4BE6 plus 4BE7), (m^3/sec) 1970-2010

Note: Compare average values for extreme low flows with the Q95 flow value of 0.349 m^3/sec.

Table 5-4: Characteristic Environmental Flow Components for Gikigie (RGS: 4BE8, 1950-2010)

Mean annual flow 0.66 m^3/sec Annual Coefficient of Variation 1.66
EFC high flow threshold: 0.637 m3/sec Q95 flow 0.052 m3/sec
EFC extreme low flow threshold: 0.089 m3/sec Q98 flow 0.029 m3/sec
EFC small flood minimum peak flow: 5.114 m^3/sec
EFC large flood minimum peak flow: 12.9 m^3/sec

Environmental Flow Component (EFC)	Minimum (m^3/sec)	Maximum (m^3/sec)	Average (m^3/sec)	Median Flow (m^3/sec)	Frequency
Extreme low flow	**0.002**	**0.089**	**0.053**	**0.053**	**10.9%**
Low flow	**0.09**	**0.637**	**0.281**	**0.250**	**64.1%**
High flow pulse	**0.639**	**4.959**	**1.301**	**1.068**	**14.4%**
Small flood	**0.639**	**11.43**	**2.541**	**1.871**	**8.0%**
Large flood	**0.641**	**20.77**	**3.070**	**2.263**	**2.7%**

Average monthly EFC **(m^3/sec)**

	Extreme Low	Low flow
Jan	**0.0505**	**0.2859**
Feb	**0.0491**	**0.2306**
Mar	**0.0475**	**0.2214**
Apr	**0.0516**	**0.2958**
May	**0.0527**	**0.3271**
Jun	**0.0706**	**0.3860**
Jul	**0.0596**	**0.3220**
Aug	**0.0585**	**0.2616**
Sep	**0.0544**	**0.2278**
Oct	**0.0555**	**0.2397**
Nov	**0.0676**	**0.3377**
Dec	**0.0760**	**0.3301**

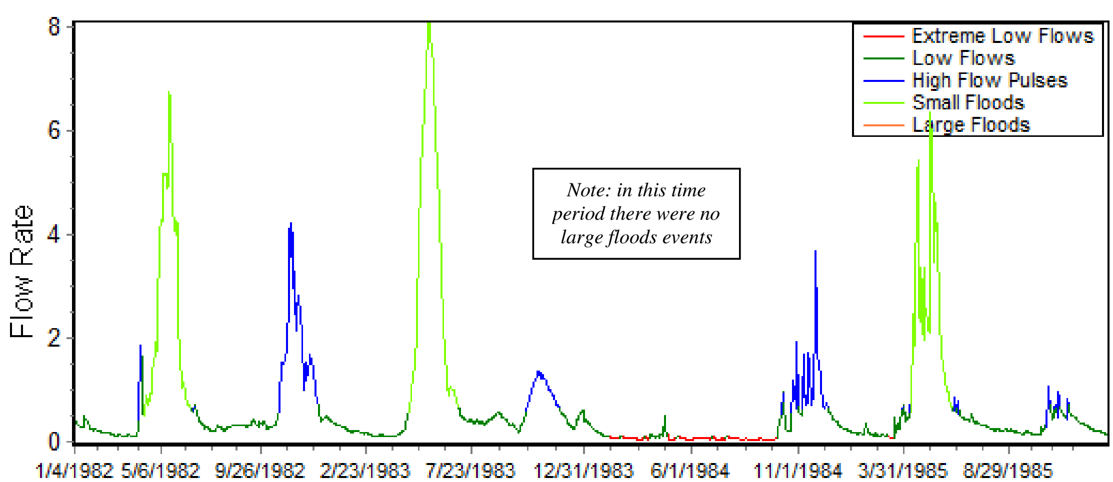


Figure 5-6: Environmental Flow Components in Gikigie River (RGS: 4BE8), and flows recorded 1982 – 1985, illustrating Environmental Flow Components

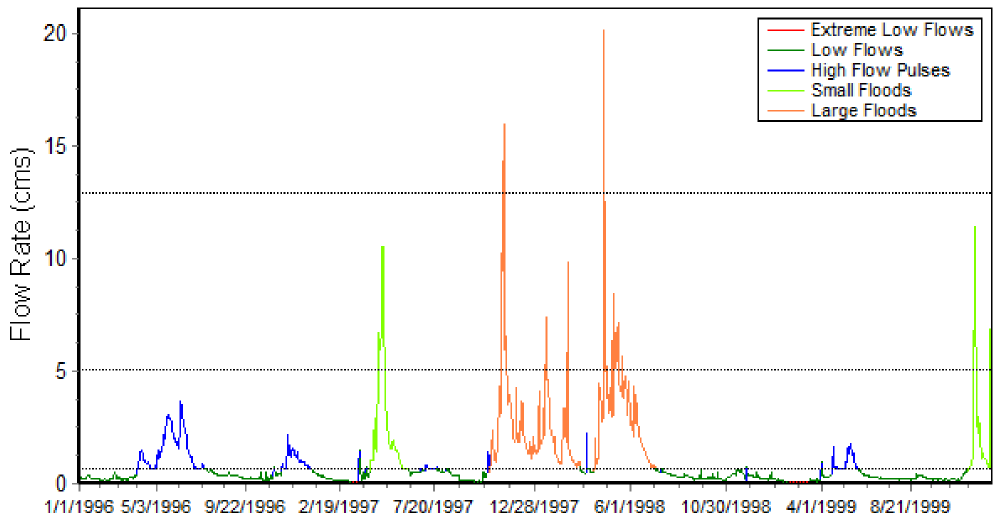


Figure 5-7: Environmental Flow Components in Gikigie River (RGS: 4BE8), and flows recorded 1996 – 1999, illustrating Environmental Flow Components, including large floods

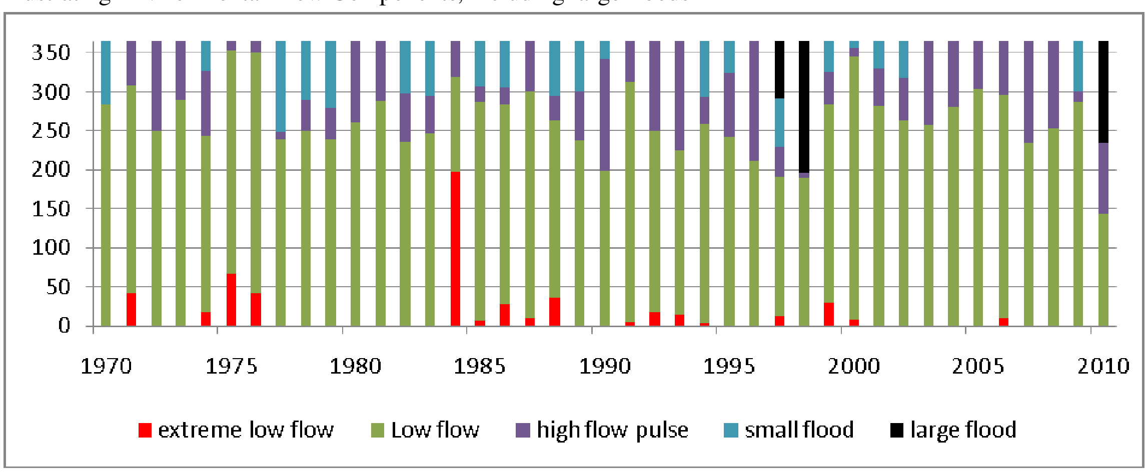


Figure 5-8: Frequency of flows in the EFC categories for Gikigie River (RGS: 4BE8), 1970-2010

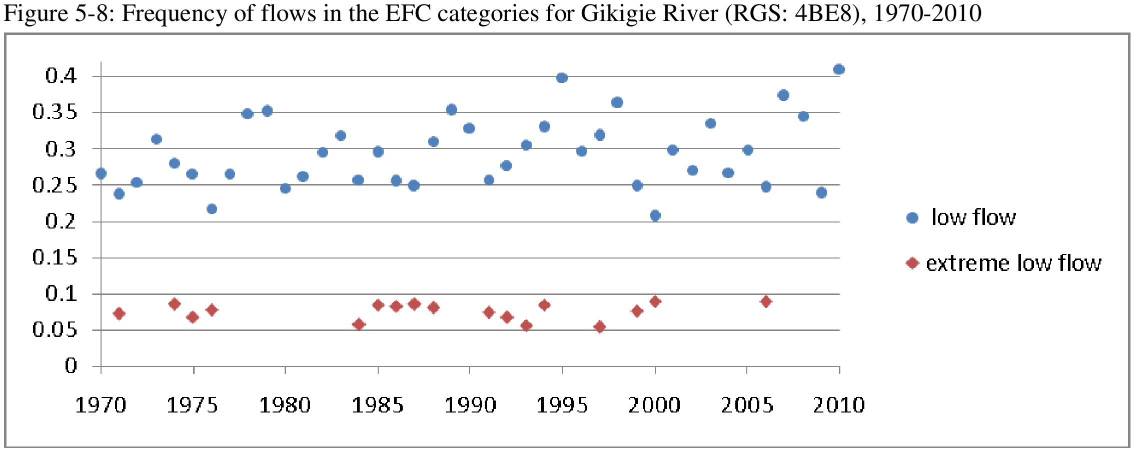


Figure 5-9: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Gikigie River (RGS: 4BE8), (m^3/sec) 1970-2010 Note: Compare average values for extreme low flows with the Q95 flow value of 0.052 m^3/sec.

Table 5-5: Characteristic Environmental Flow Components for Maragua (RGS: 4BE9, 1950-2010)

Mean annual flow 2.31 m^3/sec Annual Coefficient of Variation 0.98
EFC high flow threshold: 2.737 m3/sec Q95 flow 0.538 m3/sec
EFC extreme low flow threshold: 0.699 m3/sec Q98 flow 0.394 m3/sec
EFC small flood minimum peak flow: 10.29 m^3/sec
EFC large flood minimum peak flow: 23.27 m^3/sec

Environmental Flow Component (EFC)	Minimum (m^3/sec)	Maximum (m^3/sec)	Average (m^3/sec)	Median Flow (m^3/sec)	Frequency
Extreme low flow	**0.067**	**0.699**	**0.521**	**0.538**	**10.6%**
Low flow	**0.7**	**2.737**	**1.490**	**1.411**	**65.3%**
High flow pulse	**2.738**	**10.13**	**4.224**	**3.812**	**13.6%**
Small flood	**2.738**	**22.2**	**6.246**	**5.514**	**9.0%**
Large flood	**2.752**	**31.54**	**8.910**	**6.527**	**1.6%**

Average monthly EFC **(m^3/sec)**

	Extreme Low	Low flow
Jan	**0.542**	**1.417**
Feb	**0.489**	**1.288**
Mar	**0.477**	**1.342**
Apr	**0.502**	**1.597**
May	**0.653**	**1.767**
Jun	**0.594**	**1.854**
Jul	**0.583**	**1.584**
Aug	**0.550**	**1.356**
Sep	**0.554**	**1.287**
Oct	**0.532**	**1.374**
Nov	**0.574**	**1.751**
Dec	**0.631**	**1.649**

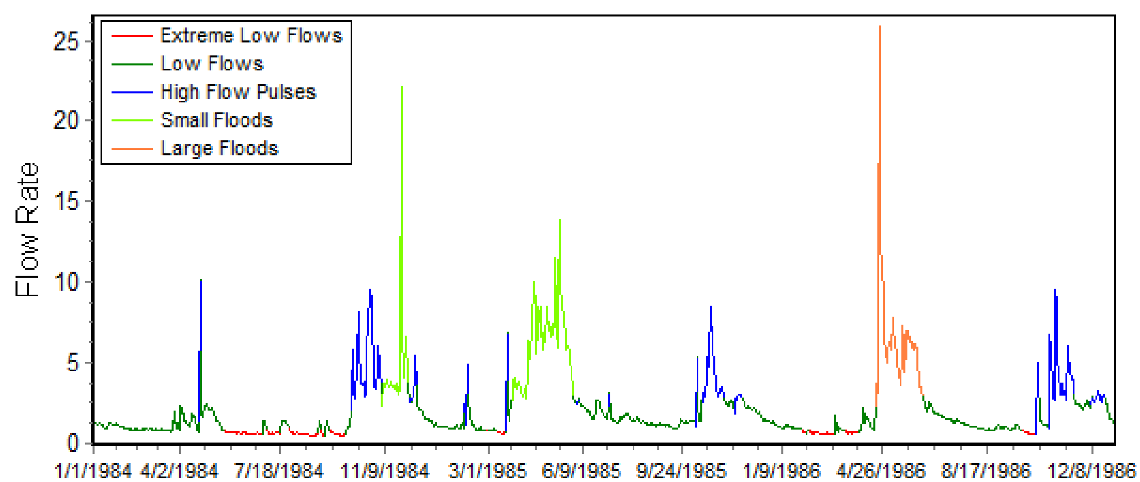


Figure 5-10: Environmental Flow Components in Maragua River (RGS: 4BE9), and flows recorded 1984 – 1986, illustrating Environmental Flow Components

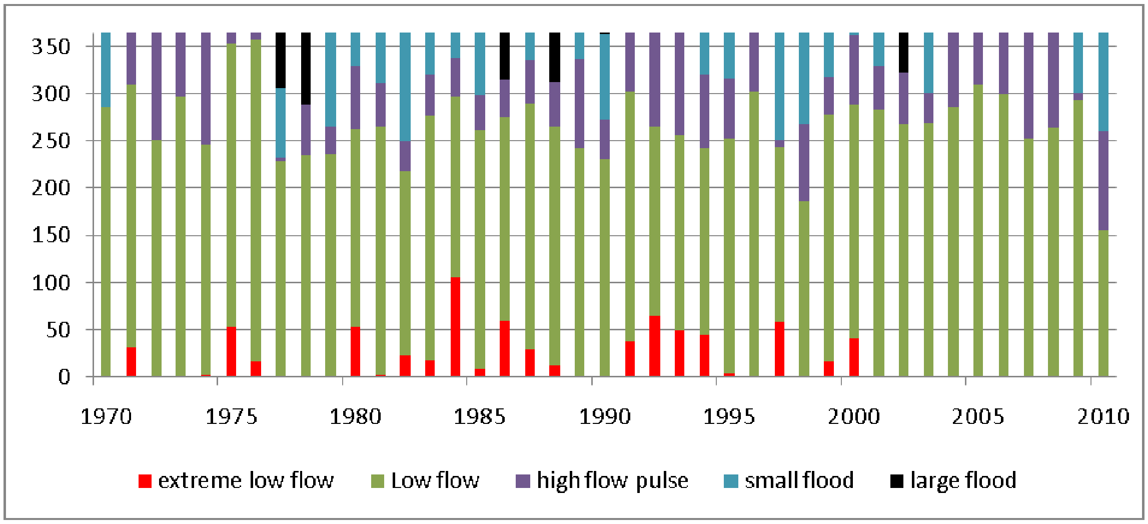


Figure 5-11: Frequency of flows in EFC categories for Maragua River (RGS: 4BE9), 1970-2010

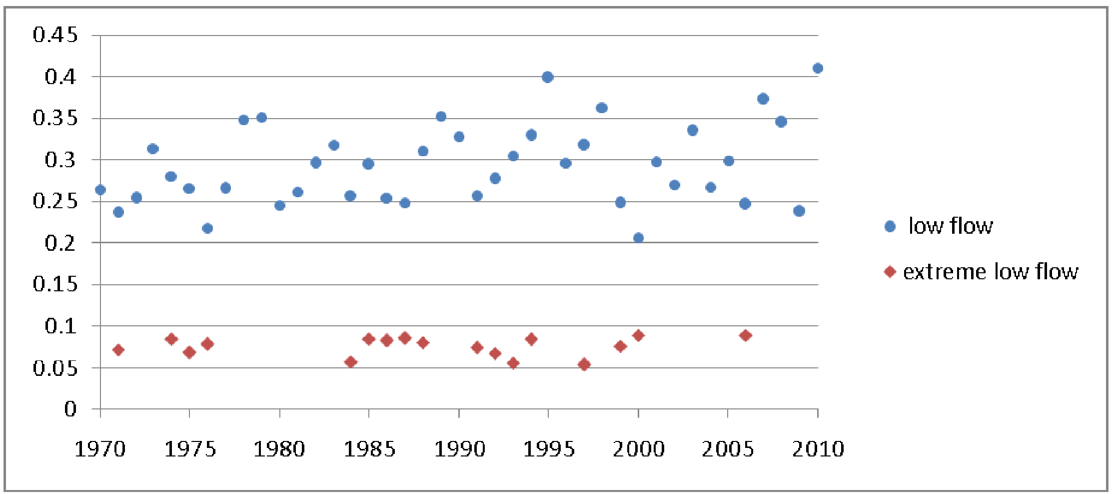


Figure 5-12: Average annual low flows (Base Flow) and extreme low flow (Subsistence Flow) in Maragua River (RGS: 4BE9), (m^3/sec) 1970-2010

Note: Compare average values for extreme low flows with the Q95 flow value of 0.538 m^3/sec.

The Extreme Low Flow Environmental Flow Components are defined as those that comprise a total of 10% of overall daily flows. In these rivers Extreme Low Flows are only experienced during about 50% of the years. For example at Maragua (at RGS:4BE9) Extreme Low Flows were only recorded during 22 out of 41 years (flow series between 1970 and 2010, see Figure 5-11Figure 5-11). However, in the driest years a significant number of all daily flows may be Extreme Low Flows. For example, in 1984, 106 days were classified as Extreme Low Flows. Q_{95} flows are similar to extreme low flows (see **Figure 5-5Figure 5-5**, **Figure 5-9Figure 5-9** and **Figure 5-12Figure 5-12**). If upstream abstraction of water for the Nairobi water supply is based on the release of constant Q_{95} flows as an environmental flow (plus additional Q_{95} to provide compensation flows) this will result in relatively low flows being the normal situation for downstream users, after the abstraction of the compensation flows. The release of 2xQ95 combined with zero abstraction for the Northern Collector when flows are below the 2xQ95 level will result in little overall change to the frequency of Extreme Low Flows, as illustrated by the flow duration curve (Figure 5-13Figure 5-13). However, the flows after abstraction will be generally lower flows than the natural situation, with no high flow pulses, and no small floods and large floods if all of these higher flows are abstracted for the Northern Collector. Long-term impacts on the environment and on downstream users are therefore likely to be significant, including negative impacts on the growing demands for agricultural production.

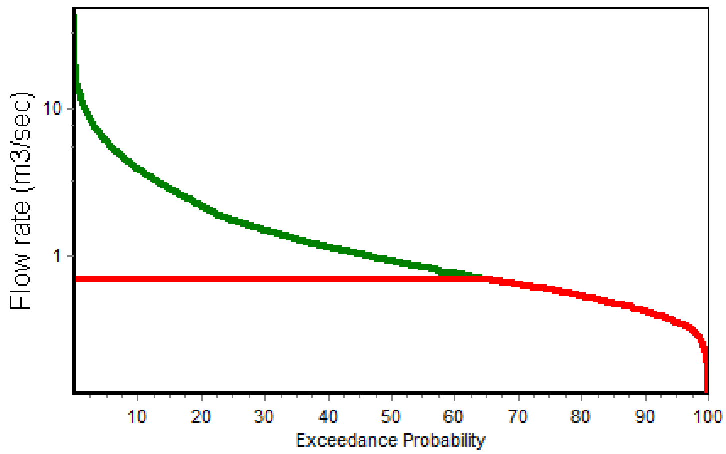


Figure 5-13: **Irati intake: Flow Duration Curves. Natural Flows (green) and Downstream Release using 2xQ95 (red)**

5.3 Options for Environmental Flow Release

Options for the release of environmental flows at each of the proposed intake structures include the setting of a minimum flow based on the Q_{95} flow, or the establishment of a set of rules for variable extraction based on the volume of incoming flows.

The option chosen in the Water Resources Options Review Report (August 2011) for downstream environmental flow release is based on Q_{95} flow as the minimum flow.

Modelling carried out for the comparison and selection of different scenarios assumed that all flows greater than Q_{95} environmental flow plus the required Compensation Flows would be diverted along the Northern Collector tunnel.

From the environmental perspective flushing with higher flows is considered essential. This provides important components of the natural hydrograph, to which the instream and downstream riparian environments as well as downstream communities are adapted. Flushing would provide significant benefits to all downstream ecosystems and would go some way towards avoiding the environmental and potential health problems associated with flatlining with constant low flow conditions.

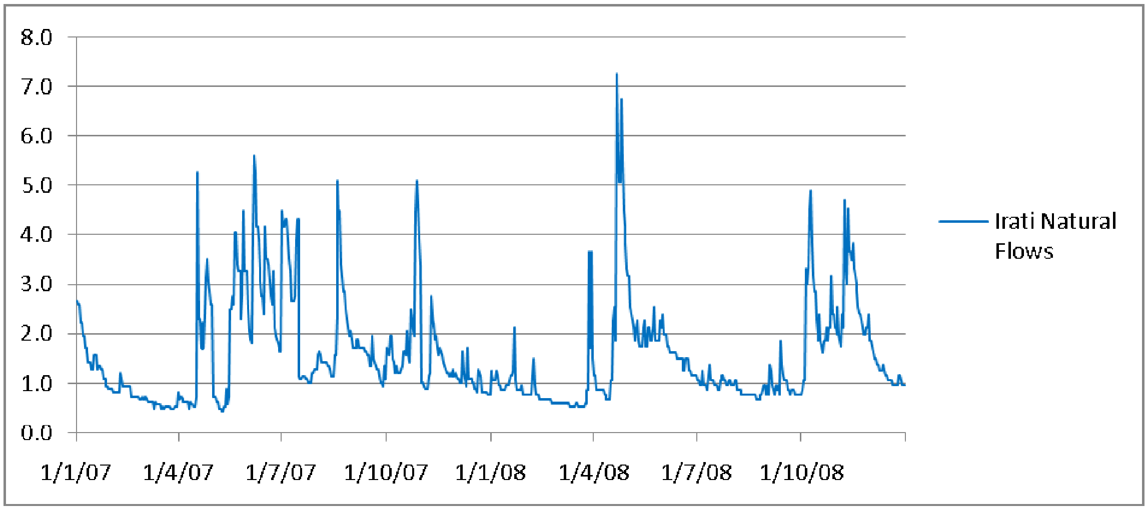
Standards have been developed and adopted in other regions for determining good ecological status with environmental flows[3]. These standards set thresholds for extraction of variable amounts depending on the volume of incoming flow and ensure that downstream environmental flows are suitable for maintaining important environmental services. An example of resulting downstream flows and flow available for extraction is illustrated by

[3] Copestake, P. & Young, A.R. (2008). How much water can a river give? Uncertainty and the flow duration curve. In: Sustainable Hydrology for the 21st Century, Proc. 10th BHS National Hydrology Symposium, Exeter.

Figure 5-14Figure 5-14 using the following recommended thresholds, before breaching the good ecological status threshold:

- for flows greater than Q_{60}, up to 40% of the flows can be taken;
- for flows between Q_{60} and Q_{70}, up to 30% can be taken;
- for flows between Q_{70} and Q_{95}, up to 20% can be taken;
- for flows less than Q_{95}, up to a maximum of 5% of the Q_{95} flow may be taken, but only if all downstream requirements are accounted for;
- for flows less than Q_{98}, 0% of flow is available for extraction ("hands off" flow).

A: Natural flows



B: Downstream flow after abstraction

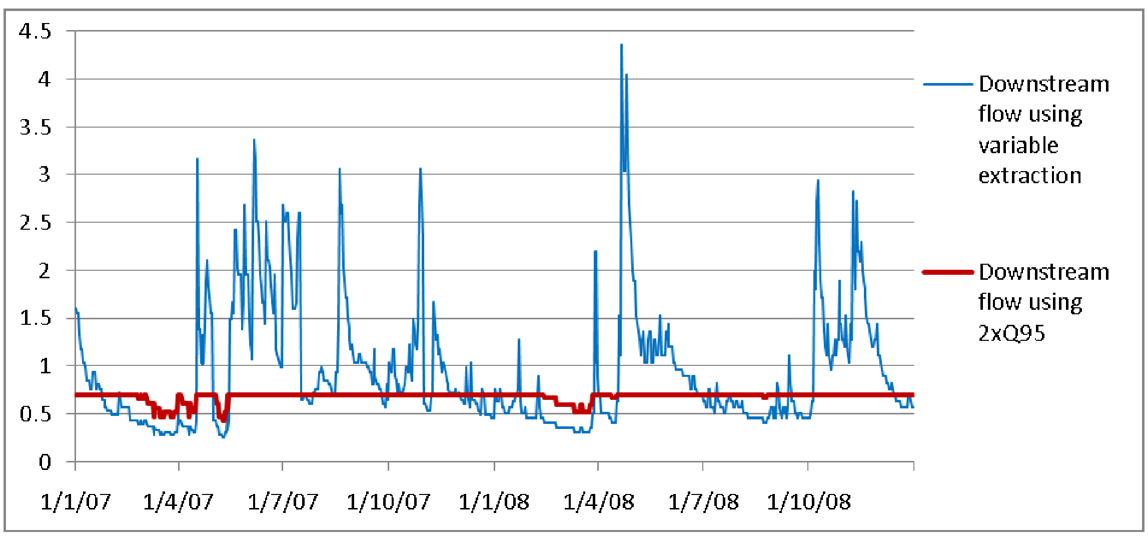


Figure 5-14: Example of downstream flows following abstraction at proposed Irati Weir (2007-2008). A: Natural Flows and B: downstream flows after abstraction using (i) the recommended thresholds for variable extraction and (ii) release of 2xQ95 after abstraction (m^3/sec).

5.4 Indicators of Hydrologic Alteration

The selected development scenario includes the initial development of the Northern Collector Phase 1 transfer to Thika dam. This is to be followed by the development of the Northern Collector Phase 2. Abstractions at a total of seven intake sites will affect the downstream flows in the following rivers:

Table 5-6: Characteristic Flows at Proposed Abstraction sites on Northern Collector

Phase	River and intake site	Flows at proposed intake sites (m^3/s)			
		EFC extreme low flow threshold	Q_{95}	Q_{80}	Q_{50}
1	Irati	0.422	0.349	0.531	0.912
	Gikigie	0.089	0.052	0.137	0.295
	Maragua	0.641	0.493	0.843	1.421
2	S. Mathioya	0.687	0.572	0.864	1.36
	Hembe	0.561	0.465	0.706	1.082
	Githugi	0.474	0.394	0.597	0.915
	N. Mathioya	1.267	1.052	1.594	2.445

*Note: Flows **based on 1950-2010 time series calculated at the intake sites.***

The Indicators of Hydrologic Alteration (IHA) method for assessing the degree of hydrologic alteration attributable to human impacts within an ecosystem was used. In this method, a series of biologically relevant hydrologic attributes that characterize intra-annual variation in flow conditions are computed and their inter-annual variation can be used as the foundation for comparing hydrologic regimes before and after a system has been altered. These parameters provide information on the most ecologically significant features of the flow regimes influencing aquatic and riparian ecosystems.

5.4.1 Range of Variability Approach

Environmental flows should be designed to maintain the integrity, natural seasonality and variability of flows, including floods and low flows. Flows were analysed using the Indicators of Hydrologic Alteration (IHA) and Range of Variability Approach (Richter et al. 1997[4]). The analysis included assessments of Hydrologic Alteration for two scenarios for release of downstream Reserve Flows:

1. Variable release — Downstream environmental flow releases using the above recommended variable abstraction rates depending on incoming flow, with the addition of downstream demands calculated by Howard Humphries and additional demands allowed for by adopting the Howard Humphries Misc Licenses figures and factoring by 1.2.
2. 2xQ95 — Downstream releases of a constant 2 x Q_{95} flow. Flows above 2 x Q_{95} would be abstracted at the intake sites. All flows less than 2 x Q_{95} would be released downstream without abstraction.

5.4.2 RVA Analysis

IHA was used to prepare a series of flow data representing the before and after downstream flow conditions using both of the above scenarios for release of Reserve Flows. These results are shown for each month in Annex 1. These before and after graphs clearly indicate the essential difference between the two approaches for delivering downstream Reserve Flows. Using RVA analysis, the expected frequencies of low, middle and high flows were calculated, with each category having an expected value of one third. IHA was then used to compute the frequency with which expected "post-impact" annual values of IHA parameters are predicted

[4] **Richter B.D., Baumgartner J.V., Wigington R, & Braun D.P. (1997). How much water does a river need? Freshwater Biology 37: 231–249.**

to actually fall within each category, and Hydrologic Alteration factors calculated. Results of the RVA analysis are given in Annex 1. These are summarized below in Table 5-7Table 5-7 and Figure 5-16Figure 5-16 which show Indicators of Hydrologic Alteration combined for all months, including the Middle, High and Low flow categories.

Results show that, as expected, abstractions will reduce the frequency of middle-level and high-level flows and increase the frequency of low-level flows. The most significant difference between the two approaches to delivering Reserve Flows (variable release or 2xQ95) is the extent to which higher flows are reduced. It is clear that release of 2xQ95 as the downstream Reserve Flows will result in a much greater alteration of the downstream hydrology, and a significant increase in the frequency of extreme low flows. This will therefore have a greater long-term impact on downstream riverine and riparian environments.

For all potential intake sites along the Northern Collector there are a significant number of Indicators of Hydrologic Alteration that show the minimum possible value of -1, indicating extreme negative alteration.

The general absence of high flow pulses, small floods and large floods, will result in inevitable long-term changes to downstream riverine and riparian environments. An example is shown in Figure 5-15Figure 5-15 which illustrates the frequency of the EFC category High Flow Pulses before and after operation of abstraction at Irati weir, using either variable release or 2xQ95 for delivery of Reserve Flows. This will also have an impact on those communities dependant on these environments, and on households or communities currently utilising the flows in the rivers, including for example, the use of water for irrigation of important commercial agricultural systems.

In contrast, Reserve Flows that are based on strategies for variable abstraction rates that depend on the volume of incoming flow exhibit smaller changes in the frequency of higher flows and the majority of parameters have smaller Indicators of Hydrologic Alteration. It is therefore considered that this general approach to the strategy for setting of procedures for downstream Reserve Flows must be adopted at the intake sites.

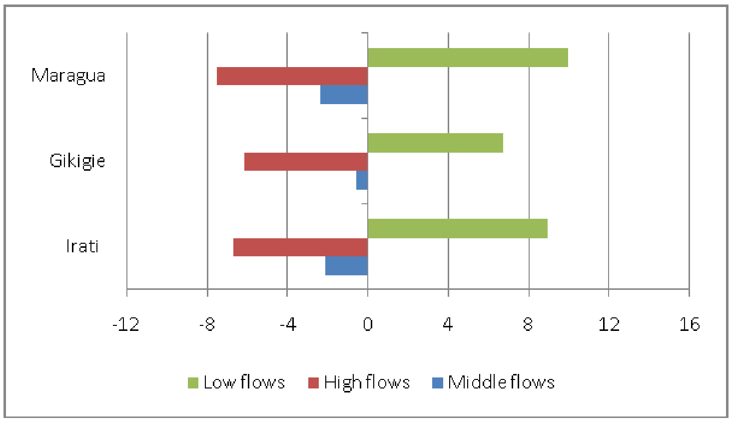
The details of the variable abstraction rates can be adapted at individual intake sites to cater for the needs of all users, for example with slightly greater volumes being abstracted from higher flows, and a higher setting for “hands-off” flows (to ensure sufficient flow for downstream demands), whilst still maintaining the underlying principle that downstream flows should be designed to maintain the overall integrity, natural seasonality and variability of flows, with a full range of flows including high flow pulses, floods, low flows, and extreme low flows.

Table 5-7Table 5-7Figure 5-15: Frequency of EFC category High Flow Pulses before and after abstraction at Irati Weir, illustrating the difference between (A) Variable Release and (B) 2xQ95 for delivery of downstream Reserve Flows.

Table 5-7: Summary of Assessments of Hydrologic Alteration on flow rates for the proposed intake sites for Northern Collector Phase 1, comparing the release of 2 x Q95 Reserve Flows with Reserve Flows generated by variable abstraction and release procedures.

	Variable abstraction and release of Reserve Flows			2 x Q95 Reserve Flows		
	Middle flows	High flows	Low flows	Middle flows	High flows	Low flows
Maragua	-2.40	-7.53	10.00	-0.29	-12.00	12.30
Gikigie	-0.57	-6.12	6.73	-10.05	-12.00	22.71
Irati	-2.14	-6.70	8.97	-1.24	-11.00	12.46

A: Variable abstraction and release



B: Reserve Flow of 2 x Q95

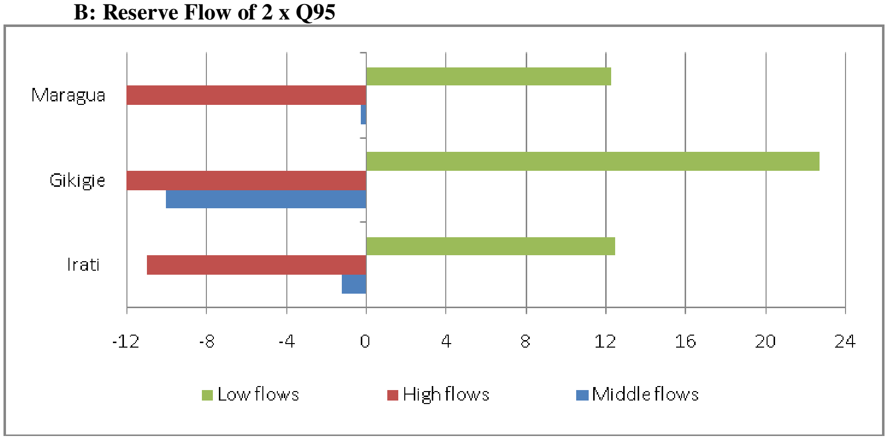


Figure 5-16: Summary of Assessments of Hydrologic Alteration on downstream flows at proposed intake sites: A). Variable abstraction and release, and B). 2 x Q95 for Reserve Flows

5.5 Compensation Flows

Compensation flows are distinct from environmental flows and are set for purposes such as downstream human uses (e.g. irrigation, livestock, hydropower, industrial or domestic use). In 2008, open surface water was recorded as a major source of drinking water for Kenyan rural households[5], with 31.3% of rural households recorded as using surface water as the source of drinking water. Districts directly impacted by the reduced downstream flows in Maragua, Gikigie and Irati Rivers will be Muranga North and Muranga South. Within these districts the 2009 National Census recorded 49.5% and 38.3% of households using rivers and streams as their water source.

Household water requirements sourced from streams was estimated from data presented in the 2009 National Census for **Muranga North District** and **Muranga South District** (**Table 5-9**~~Table 5-9~~). These data provide an estimate of 20,213 m^3/day required for household use in these two districts. However not all locations in these districts will be affected by diversions to the Northern Collector Phase 1. Those locations through which the rivers flow, or which border these rivers (Kiruri, Murarandia, Mugoiri, Kinyona, Kigumo, and Nginda) are shown in **Figure 5-17**~~Figure 5-17~~.

In addition to household water supplies from rivers/streams, there are also the demands of the piped rural water supply schemes, and commercial demands such as those of tea and coffee factories.

Households using untreated surface water such as rivers are relying completely on the regulating services of ecosystems to provide uncontaminated water in sufficient quantities. This further reinforces the importance of providing adequate downstream environmental flow releases to maintain these critical environmental functions.

The Howard Humphreys (1998) report presented estimates for total downstream demand for each river, and also indicated that a Q_{95} flow would cover the required downstream compensation flows. However, the Howard Humphries (1998) report also assumed that the environmental flows were included in the compensation flows, whereas this is clearly not the case and it is now recognised that they must be considered and evaluated separately.

At the present time, complete and reliable estimates of downstream demand are not available and estimates of compensation flows equivalent to Q_{95} flows have been used instead. The Water Sources Options Review Report (August 2011) concluded that the Q_{95} value adequately catered for the required downstream compensation flow as well as allowing for an error margin. It was only in the case of the Irati River that the estimated compensation flow was used as this was greater than the Q_{95} value.

The total in-stream flow requirement, or Reserve Flow, allocated at each diversion is therefore twice the Q_{95} flow in all rivers except Irati, in which case it was slightly higher. **Table 5-8**~~Table 5-8~~ gives the estimated minimum downstream Reserve Flow Requirement for each of the three project rivers, included in the development of the Northern Collector Phase 1 (based on compensation flow requirements reported in the Water Sources Options Review Report, August 2011).

Under the proposed operational rules, the Reserve Flow Requirement has been assigned the highest priority for supply, and will be allocated first for each project river. Remaining water resources are then allocated to meet the required abstraction at each intake site.

It is also considered essential that estimates for downstream compensation flows are required to be regularly updated based on licensed abstractions and other downstream requirements,

[5] Kenya Demographic and Health Survey 2008-09. Central Bureau of Statistics, Nairobi, Kenya

preferably on an annual basis, and that the Reserve Flows are adjusted to meet ongoing downstream demands, without imposing negative impacts on environmental flows or unnecessary constraints on development in downstream areas. There are also likely to be numerous unlicensed abstractions, and these will all need to be accounted for and included in the formal licensing system. The licensing system and allocation of licenses will need to be modified to take account of the upstream abstraction on these rivers for the Northern Collector tunnel, Phase 1.

Water for agricultural production is largely dependent on rain water. However, there have been increasing instances of crop failures. This has made rainfed agriculture unreliable in many areas. As a result, irrigated agriculture is becoming increasingly important even in areas where irrigation would not have been considered earlier. Together with the increasing population of Nairobi which will require increasing food supplies, this is most likely to result in a demand for increased use of water resources for irrigated agriculture. Alternatives to irrigation can also be promoted. These include rainwater harvesting and management (RHM) systems such as conservation tillage, on-farm runoff storage (farm ponds) and limited flood storage in earth dams/water pans for irrigation and livestock. However, if Reserve Flows are limited to the release of 2xQ95, no investment in flood storage along the Irati, Gikigie and Maragua Rivers will be possible and any existing systems will no longer be viable.

Table 5-8: Estimates for Required Minimum Downstream Reserve Flows **(m^3/s), NC Phase 1**

River	Water Supply Scheme	Design Capacity	Rural & Urban Demand,	Other demands,	Estimated Compensation Flow	$Q_{95,}$ [1]	Allocated Compensation Flow	Requ RESE FL(
Irati	Kigumo intake i7a	0.144	0.202	0.067	0.401	0.334	0.401	0.
	Kigumo intake i7b	0.132	0.008					
Gikigie	-	-	-	0.073	0.073	0.101	0.101	0.
Maragua	Kahuti Ph 4	0.378	0.059	0.073	0.482	0.65	0.65	1.
	Maragua Ridge	0.017	0.031					

1. Q_{95} flows based on naturalised 1970-2010 time series estimated at proposed intake sites
Source: Water Sources Options Review Report (August 2011).

Table 5-9: Districts directly impacted by modified downstream flows, showing proportion of households using streams and estimated requirements for household use

	Muranga North District	Muranga South District
Population (2009 National Census)	**346,283**	**432,701**
Households (2009 National Census)	**97,701**	**114,578**
% of Households using streams	**49.5%**	**38.3%**
Households using stream	**48,342**	**43,834**
household size	**3.544**	**3.776**
Estimated population using streams	**171,339**	**165,538**
Water requirements at 60 L/day per person (m^3/day)	**10,280.35**	**9,932.28**

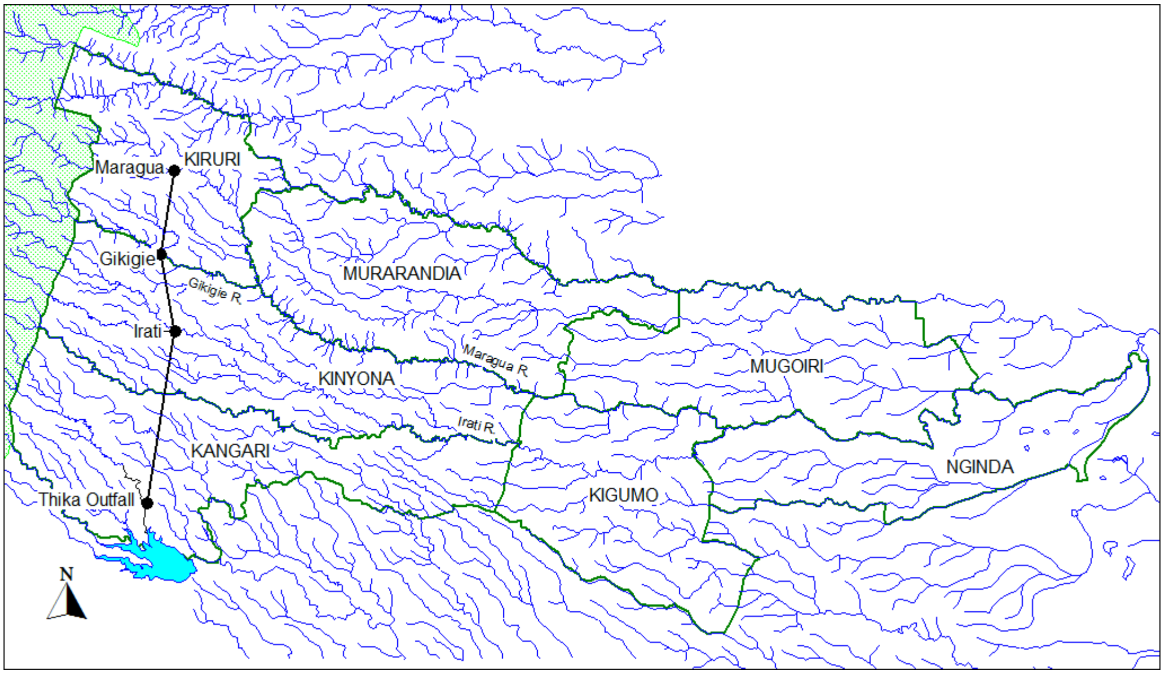


Figure 5-17: Locations in upper parts of Muranga North and South Districts (2009 National Census) through which Maragua, Gikigie and Irati Rivers flow.

5.6 Recommendations for Reserve Flow Release

The dominant flow in the rivers under normal conditions is the Low Flow, or Base Flow. This is supplemented by short periods of higher flows. There are also short and variable periods with Extreme Low Flows.

Riverine ecosystems are at their most vulnerable at times of extreme low flow. In particular this is because of a reduction in habitat availability, increased temperature extremes, reduced dissolved oxygen, a deterioration in water quality (caused by reduced effluent dilution) and habitat fragmentation (caused by natural or artificial barriers to movement). Percentiles from the flow duration curve can be used to set a minimum flow in a river so that, when the discharge falls below this level, abstractions should cease. As identified by Hirji and Davis (2009)[6], it is important to recognize that there is a physical limit beyond which a water resource suffers irreversible damage to its ecosystem functions.

By using an updated set of designs for weirs and offtakes that will be able to provide variable downstream water supplies depending on the volume of flow similar to the guidelines for variable extraction described above, it will be possible to produce a set of water supply structures that maximize potential yields at the same time as reducing negative impacts on downstream Reserve Flows. For example, incorporation of weirs with calibrated triangular, or v-notch weirs together with mechanisms for abstraction of different flows will provide for variable yields and at the same time will enable variable downstream Reserve Flows that preserve the integrity of downstream environments.

The following operating guidelines are recommended for abstraction of flows at each of the proposed weirs and intake sites on the Northern Collector pipeline, Phase 1:

- for flows greater than Q60, up to 40% of the flows can be abstracted;

[6] Hirji, Rafik, and Davis, Richard (2009). Environmental Flows in Water Resources Policies, Plans, and Projects: Findings and Recommendations. Washington, DC: The World Bank.

- for flows between Q60 and Q70, up to 30% can be abstracted;
- for flows between Q70 and Q95, up to 20% can be abstracted;
- for flows less than Q95, up to a maximum of 5% of the Q95 flow may be taken, with the proviso that all downstream Compensation Flow requirements are also catered for;
- for flows of Q98 or less than Q98, 0% of flow is available for extraction ("hands off" flow).

The resulting downstream flows would normally be capable of catering for the requirements of the Reserve Flows, including both environmental flows and compensation flows. However, to cater for the generally lower overall flow conditions that will be experienced downstream, especially with the absence of flood periods, it will be necessary to determine the specific downstream compensation flow requirements below individual intake sites and to modify the release of downstream flows to ensure that both Environmental Flows and Compensation Flows are fully catered for. In the case of very low flows, Environmental Flows should be given priority and all abstraction, both downstream and at the intake weirs, should only be available once Environmental Flows are catered for.

The above guidelines can also be extended to cater for increased abstraction during periods of higher flows, for example with the addition of a category where flows greater than Q50 could be abstracted at rates of up to 60% of the flows.

If instead of the above recommended variable abstraction guidelines, downstream Reserve Flows are set at 2 x Q95 levels (set at Q95 for environmental flows plus Q95 for compensation flows), this will result in the delivery of consistently low flows to downstream environments and to communities. Under this scenario, the environmental flows will be similar to long-term delivery of extreme low flows throughout the year (see Annex 1). It is therefore recommended that 2 x Q95 Reserve Flows be supplemented by release of high flow pulses, and some seasonal floods when these higher flows are available and form integral components of the incoming natural flows.

Other measures that can be applied to maintain good quality environmental flows and contribute towards the important high flow periods and high flow pulses required by downstream systems include time periods of "reduced extraction" in order to permit mid-level and higher flows into the deprived downstream reaches. These latter can be combined with periods of natural high flows or flood flows in order to maximise potential abstraction for the Nairobi water supply.

It should also be considered for planning purposes that securing flows for environmental purposes, or for the purpose of downstream compensation flow, from an already fully utilized river is most likely to be particularly difficult, unless users are either coerced into freeing up water, or offered incentives to do so. This emphasises the importance of taking account of all downstream environmental and compensation flow requirements at the planning and design stages – including a complete inventory of both licensed and unlicensed abstractions.

Flexibility should be built into the system, for example to enable important changes in downstream compensation requirements to be taken into account and dealt with when the needs arise. For example, the increasing population of Nairobi will require increasing quantities of food. This increased demand for agricultural produce will need to be met by an increased intensity of cultivation or production. The increased production will require an increased availability and use of water, for both crops and livestock. It is therefore considered highly likely that some areas downstream of the proposed diversion structures will require increased water supplies to meet this increased agricultural demand as the population of Nairobi increases. (see also section 6 on cumulative impacts).

5.7 Impacts from Abstraction of Flows

A "do nothing" alternative was considered to be not available. The do nothing alternative would imply that the status quo is maintained and no additional water supplies are developed. From an environmental and socio-economic perspective the do nothing alternative is not considered a suitable alternative for affected communities and for Kenya as a whole.

Relocation alternatives should also be considered as standard practice, but this is also not a suitable alternative in this case, especially for agricultural activities downstream of the proposed intake weirs. However, it is possible that a small number of water-intensive industries could relocate to suitable sites.

The selected scenario includes the abstraction of water from rivers flowing from the Aberdares and transfer of these flows through the Northern Collector tunnel to Thika Reservoir. Abstraction of water from these rivers will have impacts on environments and communities downstream of the abstraction sites as a result of hydrological alteration.

Under the chosen scenario, without Maragua Dam and the resulting storage of high flows in the reservoir, there is a greater potential for these important high flow pulses to be released downstream. The proportion of higher flows (high flow pulses, short floods, large floods) that may be released downstream in this way is currently uncertain and depends on strategies adopted by the management for release of Reserve Flows. However, their release downstream would provide significant and important advantages to downstream environments and to communities, especially on Maragua River.

As part of the Northern Collector Phase 1, there will be a requirement for downstream Reserve Flows to be maintained below the Irati, Gikigie and Maragua intakes. Similarly, under the subsequent development of the Northern Collector Phase 2, there will be a requirement for downstream Reserve Flows to be maintained below the South Mathioya, Hembe, Githugi, and North Mathioya intakes.

When considering the downstream environmental impacts resulting from hydrological alteration, the primary consideration is the strategy that will be adopted for release of downstream Reserve Flows. The adoption of procedures for variable downstream releases that depend on the upstream flows, and which attempt to maintain the range of different components of the natural flow regime in order to sustain riverine ecological integrity, will help to ensure the maintenance of downstream environments. Instead, if downstream Reserve Flows are set at 2 x Q95, without the inclusion of additional high flow pulses and floods, the abstraction of water along the Northern Collector, Phases 1 and 2, will result in increased hydrological alteration and increased levels of downstream environmental impact.

Impacts therefore depend on the strategy adopted for release of downstream flows. The options include the following:

• Reserve Flows set at and limited to 2xQ95 (compensation flow + environmental flow)	Serious Impacts are expected	Impacts will be Long-Term. There will be minimal protection offered to downstream environments and to communities and households requiring access to the water resources.
• Reserve Flows released as a variable release depending on the upstream flow volumes.	Reduced Impacts that will be manageable	Impacts will be manageable as a result of the release of Reserve Flows that include the presence of adequate high flow pulses and some small floods, and an overall flow regime similar to a natural flow regime.

Treatment of Waste Water

As a result of reduced downstream flows, the issues relating to water quality will need to be carefully considered, particularly in relation to the treatment and discharge of (a) household sewage and (b) the waste from industrial water use.

Industrial water supply is normally incorporated in the domestic water supply which serves both domestic and industrial needs. Water quality requirements for domestic and industrial water are not separated. As a result, clean water, which is treated for domestic use, is utilised for industrial activities, construction and other uses. The wastewater characteristics of the domestic and industrial water systems are fundamentally different. There is therefore need for industries to pre-treat their wastewater before discharging into the public sewers. With the reduced downstream flows in the Irati, Gikigie and Maragua Rivers there will therefore be a need to ensure that all industrial waste water is adequately pre-treated before disposal.

5.8 Recommendations for Operating Rules

A policy for abstraction of variable amounts depending on the natural flow is recommended. Recommendations for operating rules at each of the proposed abstraction sites along the Northern Collector will need to be defined during detailed design stages. It is clear that the preferred option should be a set of operating rules based on variable abstraction rates, and that these will provide the best mechanism for providing downstream Reserve Flows.

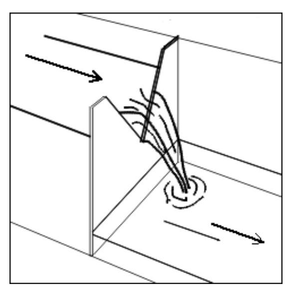
However, at the current pre-design stage it has not yet been possible to consider the variable abstraction recommendations when computing yields and water balances due to the range of potential options at each abstraction site, and due to the time required to set up the operation rules to be incorporated in the model, as well as the resulting consequences on yields. At the current pre-design stage, therefore, the computation of yields and the overall water balance modelling has been prepared assuming a constant 2 X Q95 at each abstraction site.

Recommendations for required designs and operating procedures to be defined at the detailed design stage include the following:

- Development and refinement of the recommended guidelines for variable abstraction and variable downstream flow release to enable computation of yields and water balances, whilst at the same time maintaining both downstream Environmental Flows and downstream Compensation Flows. These guidelines will need to be determined independently for each abstraction site depending on the specific requirements for Compensation Flows.

- Design of calibrated triangular, or V-notch weirs at each abstraction site together with mechanisms for abstraction of variable flows. This will provide for variable yields and at the same time will enable variable downstream Reserve Flows that preserve the integrity of downstream environments, and provide vital resources to downstream communities and households reliant on these water resources. Installation of V-notch weirs is also important because Triangular or V-notch weirs measure low discharges more accurately than horizontal weirs. V-notch weirs should always be used when frequent low flows are included in the overall range to be measured.

V-Notch Weir



- Designs for fish ladders need to be reviewed and fully incorporated in the designs of all proposed weirs. Sufficient flow must be allowed for and passed downstream through fish ladders, particularly at those times of year when fish and other aquatic species are likely to require to move upstream or downstream, e.g. for purposes of breeding. This is likely to be at times of natural high flow pulses and small floods. Operating rules should therefore allow for the passage of sufficient flows to enable these important movements to take place.

- As part of the downstream Compensation Flow requirements, it will also be important to consider and incorporate the likely increases in the future requirements for irrigation supplies to provide agricultural produce to an increasing population in Nairobi and adjacent areas, whilst maintaining important agricultural production resulting in foreign earnings.

- In cases where downstream water requirements are likely to be constraining factors, e.g. for agricultural requirements, the incorporation of small impoundments or other water storage facilities should be considered at selected downstream sites. Any such sites, either proposed or existing, should be incorporated within the operating procedures.

- Operational procedures will need to be established so that, under periods with naturally low flows (e.g. extreme low flows), sufficient flows are allocated to:

  a. Cater for downstream demands from communities, households, agriculture (crops and livestock), and **commercial or industrial requirements**,

  b. Provide environmental flows of sufficient quantity to prevent critical decline of downstream aquatic environments,

  c. Ensure the maintenance of water quality (including the requirements related to sewage treatment and disposal), and

  d. Provide some flow for Nairobi water supplies whilst taking account of available storage in reservoirs. Rationing of water to all consumers may need to be considered under such circumstances.

- A "*hands off*" flow (HoF) will also need to be defined below which no extraction or diversion of water can take place. As part of the variable abstraction guidelines, the currently recommended absolute "hands off" flow specifically for environmental purposes would be flows equal to the Q98 flow, plus the required Compensation Flows. Depending on specific downstream demands and associated Compensation Flow requirements (household water needs, livestock requirements, subsistence irrigation, commercial irrigation, and other commercial or industrial requirements), mechanisms will need to be defined to enable to adjustment of this hands-off flow level so as to ensure adequate flows to sustain these downstream environments and communities. For example, if Compensation Flow is required at the Q95 flow level, then the hands off flow would be set at Q95 + Q98.

- In situations where downstream flows, e.g. at Maragua RGS: 4BE1, are likely to be less than the minimum Q98 level, or where there is potential for zero flows, increased releases must be made from all of the upstream intake weirs in order to compensate for these very low flows.

- An important recommendation is that all river flows must be monitored on a regular daily basis both above and below each of the weirs and intake structures. Together with other flow data, the flows will then be available to form the basis for day-to-day operational management decisions.

- Regular monitoring and updating of downstream water abstraction and use will need to be carried out. This includes, for example, the use of water by households and communities, or for use as irrigation supplies. This should include both licensed and unlicensed abstractions. This information will need to be fed into regular operating procedures in order to optimise the use of available water resources and continue to provide environmental flows capable of maintaining downstream environments and critical environmental services.

- It is recommended that the Water Management Authority should formulate a catchment management strategy for the management, use, development, conservation, protection and control of water resources within each catchment area. This should include mechanisms for enabling communities to participate in managing the water resources within these catchments. The Authority should also appoint a catchment area advisory committee.

The abstraction of water at the proposed sites for the Northern Collector Tunnel, Phase 1 will inevitably result in the creation of a relative water scarcity situation downstream of these sites. The following Policy Message and Recommendation from the "Kenya, State of the Environment and Outlook 2010" report[7] are particularly relevant when considering the requirements for operating rules for downstream Reserve Flows below the abstraction sites.

> **Policy message:** *Given the linkages between water and human and environmental health as well as the major sectors of the economy, access to clean and safe water in adequate quantities is a prerequisite for the attainment of Vision 2030. It is therefore vital that measures are urgently instituted to address the water scarcity challenge that the country is currently grappling with especially in light of the fact that this crisis is projected to rapidly worsen as population increases and climate change and their derivative effects take their toll.*
>
> **Recommendation:** *Ground the concept of integrated water resources management (IWRM) which takes cognizance of the multi-faceted nature of water problems and calls for comprehensive management of water resources based on an ecosystem approach and an appreciation of the needs of the diverse users and the broad range of potential impacts of water use.*

[7] NEMA (2011). KENYA State of the Environment and Outlook 2010. Supporting the Delivery of Vision 2030. Summary For Decision Makers. National Environment Management Authority, Kenya.

6 Cumulative Impacts

The Gikigie River joins the Maragua River approximately 4.8 km below the proposed Gikigie Intake Weir. Further downstream, the Irati subsequently merges with the Maragua River after flowing for 29 km. Below these junctions, impacts from reduced flows released at the Intake Weirs will be related to the combined releases from each weir. Records from the river gauge at Maragua (RGS:4B1) represent flows below the junction of all three rivers and enable an assessment of the changes in flow at this point to be estimated. RGS:4BE1 lies approximately 22 km along the course of the Maragua river below the junction with the Irati. Flows at this point include flows from a larger catchment that includes additional tributaries originating from below the Aberdare Forest boundary.

Cumulative impacts at Maragua 4BE1 are expected to include the following primary considerations:

1. Reduced flows as a result of diversion of a majority of the flows originating from the Aberdares at Irati, Gikigie and Maragua intakes to the Northern Collector, resulting in:
2. Reduction in the flow reaching Masinga Reservoir and therefore a reduced flow available for hydroelectric power generation.
3. Some short periods or single days with potentially zero flow. These periods will normally be preceded and/or followed by further periods with extreme low flow.
4. Less flow available for use in current and future agricultural activities in downstream areas (irrigation), in order to provide food required by the increasing population of Nairobi.

Cumulative impacts may also arise from additional factors or developments not directly related to the upstream diversion of water via the Northern Collector tunnel to Thika Reservoir. Effects from different activities may also interact to cause additional effects not initially apparent when considering the individual developments or changes, and there may also be synergistic interaction between different factors.

Potential factors that may ultimately interact with impacts from changed downstream flows on the Irati and Maragua Rivers include the requirements for increased food resources for an increased population in Nairobi, some of which may require increased use of irrigation. Siltation of Masinga reservoir is also a factor that is likely to interact with the changes in flow. Reduction of reservoir capacity by 30% by 2050 due to siltation is considered likely[8]. Potential factors also include the longer term impacts of climate change as well as the potential changes that are likely to be brought on by "peak oil" and the increase in international oil prices. The increase in oil price is likely to result in less daily movement between Nairobi and adjacent areas, and a resulting shift in demand for water from Nairobi to the adjacent areas. Increased oil prices may also put increased pressure for development of hydropower, including mini-hydro. Trends in Brent Oil crude prices are indicated by Figure 6-5Figure 6-5. However, the potential interactions with impacts related to both climate

[8] Droogers, P. (2009). Climate Change and Hydropower, Impact and Adaptation Costs: Case Study Kenya. Report Future Water: 85.

Hoff, H., Noel, S. and Droogers, P. (2007). Water use and demand in the Tana Basin: Analysis using the Water Evaluation and Planning tool (WEAP). Green Water Credits Report 4, ISRC - World Soil Information, Wageningen.

change and international oil prices are less likely to be directly relevant within the time period up to 2017, but may increase in relevance thereafter.

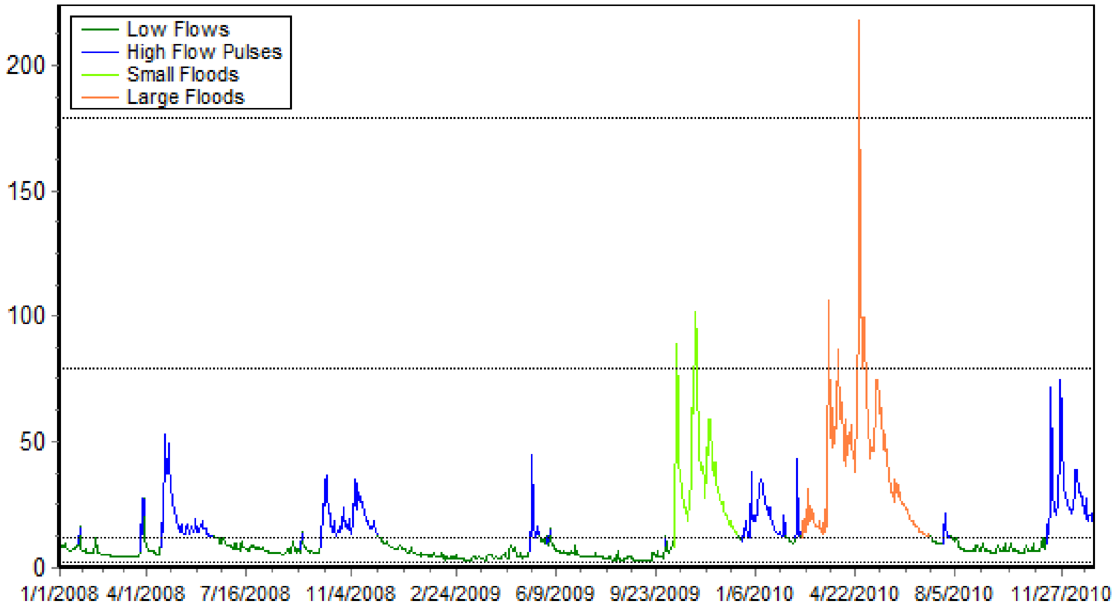


Figure 6-1: Flows at Maragua RGS:4BE1, 2008-2010 (m^3/sec), illustrating characteristic seasonal patterns of flow with occasional periods of small floods and large floods (extreme low flows were not recorded during this period).

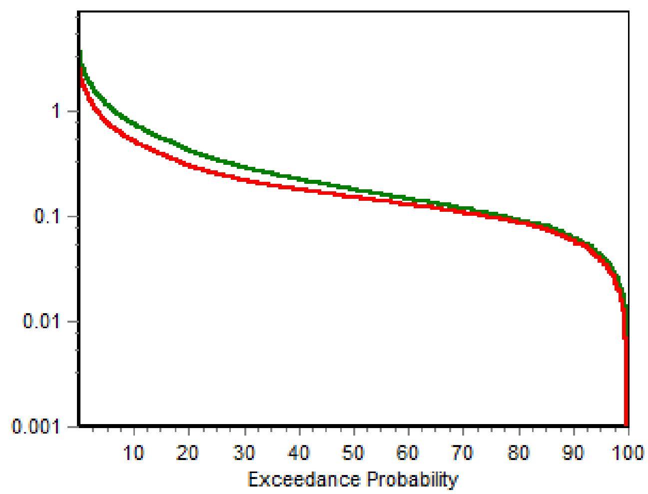


Figure 6-2: Flow Duration Curves at Maragua RGS:4BE1. Natural flows (green). Change following abstraction for Northern Collector and release of 2xQ95 (red).

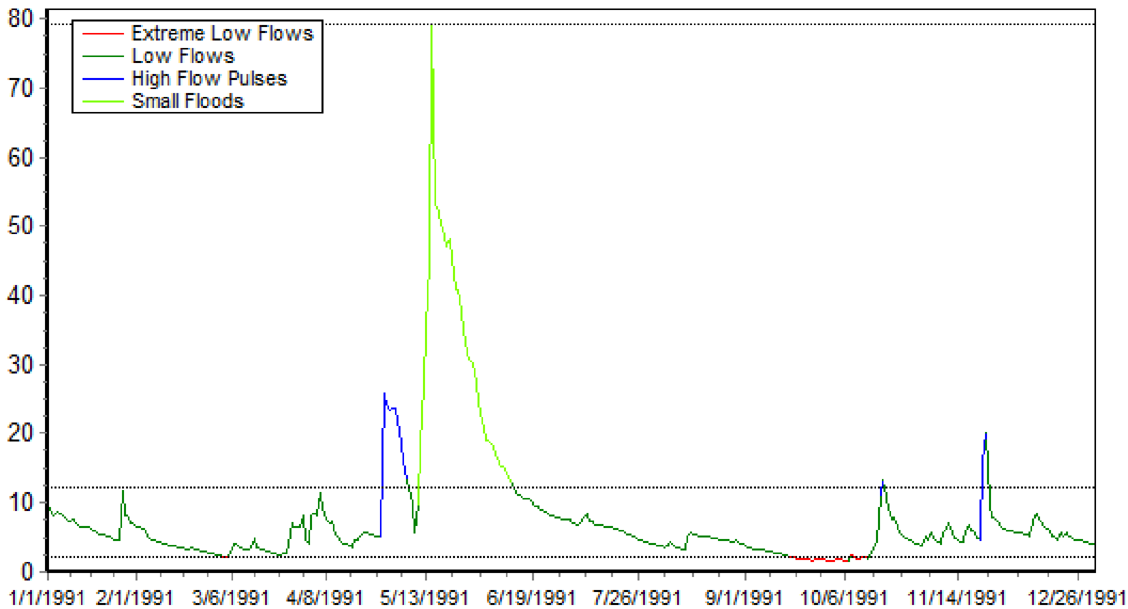


Figure 6-3: Natural Flows at Maragua RGS:4BE1 during 1991 (m^3/sec), illustrating a period with extreme low flow.

	Flows (m^3/sec)		
	Natural	Modified	Change
Jan	7.939	6.426	19.1%
Feb	5.136	4.411	14.1%
Mar	5.304	4.382	17.4%
Apr	20.898	14.752	29.4%
May	32.183	22.029	31.5%
Jun	13.149	9.751	25.8%
Jul	7.268	6.020	17.2%
Aug	5.371	4.699	12.5%
Sep	4.447	3.959	11.0%
Oct	7.287	5.664	22.3%
Nov	17.707	12.335	30.3%
Dec	12.146	9.069	25.3%
Ann.	11.570	8.625	21.3%

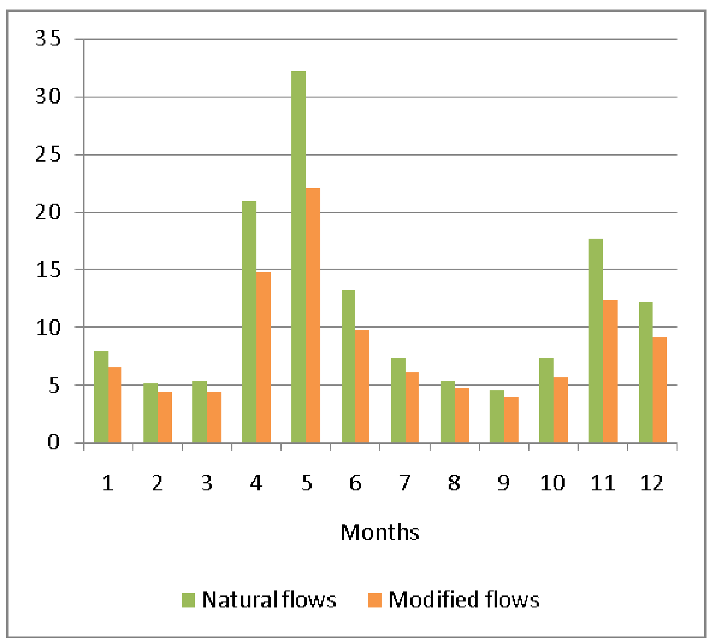


Figure 6-4: Flows at Maragua RGS:4BE1 (1950-2010). Differences between the average monthly Natural flows and Modified flows with 2xQ95 released at Northern Collector intakes

Changes in Flow in Maragua River at RGS:4BE01

Natural flows at Maragua RGS:4BE01 are illustrated by the flow patterns shown in Figure 6-1~~Figure 6-1~~, and the flow duration curves in Figure 6-2~~Figure 6-2~~ which illustrate the change following abstraction at the Northern Collector Phase 1 weirs (Maragua, Gikigie and Irati) and release of 2xQ95 Reserve Flows. The differences between the average monthly natural and modified flows are shown by Figure 6-4~~Figure 6-4~~.

The possibility of upstream abstraction resulting in short periods, or single days with zero flow downstream can be illustrated by recorded natural flows during 1991 and estimates of modified flows. For example, in 1991, a period of 27 days with extreme low flows under natural flows (see Figure 6-3~~Figure 6-3~~) results in, following upstream abstraction and release of 2xQ95, a period of 7 days with zero flow and a further 5 days with flows of less than 0.5 m^3/sec. Modelling changes in flow using the 1950-2010 time series results in 0.33% of daily flows equal to zero (73 out of 22,280 days), and 1.04% of daily flows of less than 0.5 m^3/sec. The extreme low flow threshold for natural flows at 4BE1 is 2.2 m^3/sec. These zero flow periods can be mitigated by the release of greater flow volumes from the Northern Collector intake sites at those times when these zero flows or very low downstream flows are considered likely.

Mean annual flow reaching Masinga Reservoir from Maragua River can be expected to be reduced by the diversion of upstream flows into the Northern Collector tunnel. Available published information on average monthly flows into Masinga Reservoir are indicated in Table 6-1~~Table 6-1~~, (1995-1997). Taking the daily 1995-1997 flow data from Maragua 4BE1, modified to include upstream abstraction for the Northern Collector with release of 2xQ95 Reserve Flow, results in an overall annual average reduction of inflow of 3.17% for inflow to Masinga Reservoir, or a reduction in volume of 3.94 m^3/s relative to average inflow of 124.33 m^3/s (1995-1997). Flows in the Tana downstream of Masinga Reservoir can also expect o be reduced.

Table 6-1: Average flows into Masinga Reservoir (m^3/sec), and potential changes following diversion of water to the Northern Collector Phase 1

	Masinga 1995	Masinga 1996	Masinga 1997	Masinga Average 1995-97	Maragua 4BE1 natural	Maragua 4BE1 modified	Masinga with modified 4BE1	% change
January		103.3	21.83	62.57	4.42	3.58	61.73	1.34%
February	10.05	86.71	13.59	36.78	5.06	4.52	36.25	1.46%
March	49.32	57.35	16.08	40.92	5.08	4.37	40.21	1.72%
April	679	36.47	169	294.82	14.53	9.38	289.68	1.75%
May	289.8	70.27	363.9	241.32	28.46	17.50	230.36	4.54%
June	253.7	119.7	287	220.13	12.68	8.39	215.84	1.95%
July	170.8	122.8	187.5	160.37	7.87	6.01	158.51	1.16%
August	99.25	82.22	83.38	88.28	6.04	4.70	86.94	1.52%
September	61.01	41.61	26.59	43.07	4.86	4.02	42.24	1.94%
October	39.06	15.39	175.9	76.78	14.35	10.55	72.98	4.96%
November	26.77	25.24	255.7	102.57	37.74	25.33	90.17	12.09%
December	86.91	27.64	300.9	138.48	16.48	11.88	133.89	3.32%
Average	152.74	69.19	145.50	122.47	13.25	9.31	120.39	3.17%

Source: van Loon, A. and Droogers, P. (2006). Water Evaluation and Planning System, Kitui - Kenya. WatManSup project. WatManSup Research Report No 2.

These Masinga inflows compare with the estimated mean discharge of 91.28 m^3/s for the period from 1957 to 1990 at Masinga quoted by the “Mutonga/Grand Falls Hydropower

Project Feasibility Study Report" (March 1998), where discharge includes additional factors such as evaporation and other losses from the Reservoir.

In areas adjacent to the Northern Collector intakes agricultural activities are predominantly tea plantation. The small areas under food crops are for subsistence farming are not for sale to Nairobi. At lower elevations below the tea zone, the predominant agriculture is commercial coffee. The agricultural potential in Muranga District generally decreases from northwest to southeast, mainly because of decreasing rainfall and soil fertility. In areas with less rainfall, and with a reduced proportion of commercial tea and coffee, an increasing demand for food crops required by the increasing population of Nairobi is likely to lead to an increased demand for irrigation. For example, in July 2010, it was reported that farmers in Muranga District would benefit from KSh50 million to help them invest in irrigation schemes (Daily Nation, July 10 2010) and that 17 schemes would use sprinkler, hose, and drip methods of irrigation. With an increase in the local population in areas downstream of the Northern Collector intakes, coupled with an increase in demand for food from a greater population in Nairobi, it is considered likely that there will be increased pressure for use of available resources for irrigation in suitable sites within relatively easy transport distance from Nairobi. With an increase in the local population in the Muranga area, and an increase in demand for food from greater populations in Nairobi and satellite towns, it is considered likely that there will be increased pressure for use of available resources for irrigation and improved soil water management. However, the decreased flow at Maragua RGS:4BE1 of about 3.7% (based on 3 years of monthly flow data) does indicate that the overall impact of abstraction for the Northern Collector is relatively small.

The National Water Resources Management Strategy acknowledges the issue of agricultural requirements for water:

> 'Since the agricultural sector accounts for a large proportion of water use in Kenya, introduction of water demand management in this sector is imperative. More efficient irrigation approaches and technologies should be adopted. These include:
> (i) Assessing the irrigation potential of soils in terms of water loss. This includes determining soil texture, moisture retention properties and the slope and then choosing the mare water efficient soils
> (ii) Identifying the suitable water saving technology and the efficient production level.'

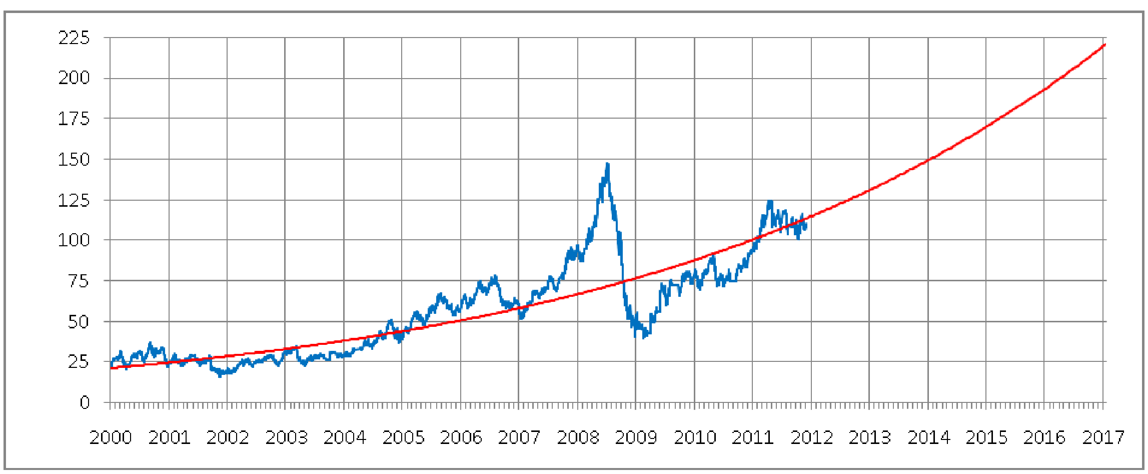


Figure 6-5: Trends in international crude oil prices: Daily Brent Crude 2000-2011 (**US$ per barrel)**, with best-fit trend line (power curve, R^2=0.801) extended to forecast till year 2017.

7 Upstream Catchment Areas

7.1 Catchment Protection

Deforestation in the Aberdare Range and reduced vegetation cover in the other parts of the river catchments would inevitably result in increased runoff during higher rainfall periods and in increased turbidity and suspended solids in the river flows. This would result in siltation at the weirs and intakes, as well as in downstream reservoirs, and requirements for more expensive water treatment.

An important and major part of the catchments of the proposed Northern Collector weirs and abstraction sites are included within the protected areas of the Aberdares, including the Aberdare National Park and neighbouring Aberdare Forest Reserve. Significant parts of all of the catchments associated with the proposed Northern Collector schemes are therefore considered to be under a "high" protection status. Major parts of each catchment lie within the Aberdare Forest Reserve land (see Figure 7-1Figure 7-1), with a smaller portion of the upper catchments within the National Park. It is recommended that the Forest Reserve land is managed to provide maximum catchment protection, and that any potential deforestation in these areas is minimized.

Much of the land within the catchments outside the protected areas consists of relatively steep sided valleys, with roads and households largely limited to the higher land between valleys, or in some flatter areas in valley bottoms. Land use and land cover includes smallholder tea as the dominant crop (see Figure 7-2Figure 7-2), together with small areas of smallholder cultivation of annual food crops, and woodlots, as well as significant amounts of natural riparian vegetation along river banks. Cultivation on such steep sided valleys requires terracing in order to reduce the risks of soil erosion. Terracing is encouraged under smallholder tea (see below) and it is recommended that efforts to promote sustainable land management for tea and all other crops should be actively supported by the project. The utilisation of the riparian zone of all rivers, both perennial and seasonal, is governed by restrictions, under which no tillage or cultivation is permitted and the draining of wetlands and **swamps is subject to permits issued by the Authority (WRMA).**

Costs of active support for catchment protection will be minor. Improved sustainable land management will also provide benefits to the local communities.

Below the diversion structures on the Northern Collector schemes it is also recommended that regular land management and control measures will be required for catchment protection, in particular in order to reduce the risks of soil erosion. Where possible this should be combined with local on-farm water harvesting measures and agricultural practices such as Conservation Tillage. In particular Conservation Tillage limits soil loss and decreases erosion, enhances soil structure and nutrient status, reduces runoff, conserving soil moisture and therefore limits requirements for external water sources. This will require a comprehensive sustainable land management plan adopted and managed by all of the relevant ministries involved – including water, agriculture and environment.

The impacts related to catchment protection are considered to be "manageable issues" with no negative impacts. However, the longer term benefits resulting from improved and sustainable land management are expected to be significant and should in the long-term override the costs.

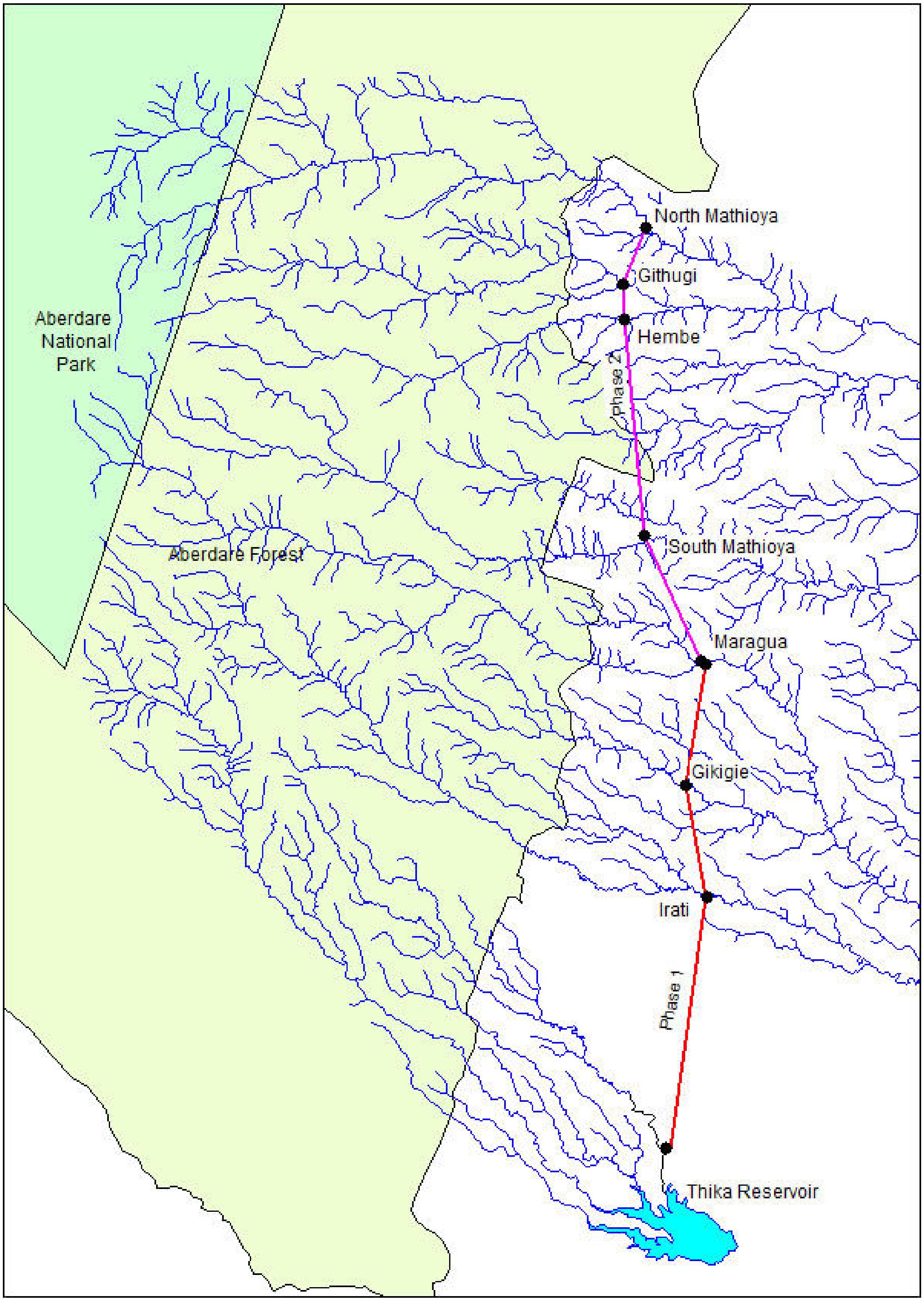


Figure 7-1: Northern Collector tunnel (including Phase 1 and Phase 2) and Thika Reservoir: Showing Protected Forest areas, National Park land, and rivers connected to the project

Figure 7-2: Land use adjacent to site of proposed Maragua Intake Weir, illustrating Smallholder Tea as dominant land use

7.2 Water Quality

Runoff from agriculture and development, including pollution from septic systems and sewers, and other human-related activities increase the flow of both inorganic nutrients and organic substances into ecosystems. For example, excess levels of Phosphorus are often linked to point-source pollution from sewage. The primary requirements for provision of good quality water supplies will be to:

- Minimize negative impacts of upstream land use on water quality, including runoff and erosion.
- Prevention of excess nutrients entering the drainage systems.
- Prevention of agricultural pesticides and herbicides entering the rivers, as well as
- Minimizing change in woody cover and land use within the catchments.

Primary impacts will be related to land use within the catchments, and specifically to changes in woody cover and agricultural land use. The major parts of each catchment lie within the protected areas of the Aberdares and are therefore unlikely to change. Important land use within the settled parts of the catchments includes smallholder tea plantation, smallholder agriculture, and woodlots. Smallholder tea is the dominant land use.

Much of the land within the catchments has relatively steep slopes and maintenance of appropriate land use and land cover on these slopes will be an important consideration. The growing of tea represents an important land cover, especially on the steeper slops. Whilst changes associated with the construction and operation of diversion structures may result in some changes in land use in the immediate area of each diversion structure, these are considered

TO BE RELATIVELY MINOR AND, IMPORTANTLY, SHOULD BE MANAGEABLE AND SHOULD NOT HAVE AN IMPACT ON WATER QUALITY.

THE VARIOUS RIVER SOURCES EXAMINED AND REPORTED IN THE HOWARD HUMPHRIES REPORT (1998) WERE OF SIMILAR QUALITY AND THE WATER SUITABLE FOR USE AS WATER SUPPLIES GIVEN APPROPRIATE TREATMENT. POSSIBLE CHANGES IN THE MANAGEMENT OF SMALL SCALE AGRICULTURAL LAND IN SMALL PARTS OF THE CATCHMENT IN THE INTERVENING YEARS MAY RESULT IN INCREASED RUNOFF FROM CULTIVATED AREAS. HOWEVER, IT IS CONSIDERED THAT AFTER STORAGE AND APPROPRIATE TREATMENT THE WATER WILL BE SUITABLE AS A SOURCE FOR POTABLE SUPPLY.

IT WILL BE NECESSARY TO CARRY OUT REGULAR WATER QUALITY ASSESSMENTS AS PART OF FUTURE MANAGEMENT STRATEGIES. THIS WILL CONTRIBUTE TOWARDS APPROPRIATE AND SUSTAINABLE LAND MANAGEMENT PROCEDURES WITHIN THE CATCHMENTS, FOR EXAMPLE LIMITING THE APPLICATION OF AGRICULTURAL CHEMICALS AND A FOCUS ON improved water and land management.

As part of long term land management approaches designed to promote water quality, it is recommended that measures to promote Conservation Agriculture should be adopted. Based on the FAO definition, Conservation Agriculture (CA) is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological procESSES. SOILS UNDER CA HAVE VERY HIGH WATER INFILTRATION CAPACITIES REDUCING SURFACE RUNOFF AND THUS SOIL EROSION SIGNIFICANTLY. THIS IMPROVES THE QUALITY OF SURFACE WATER REDUCING POLLUTION FROM SOIL EROSION, AND ENHANCES GROUNDWATER RESOURCES.

7.3 Importance of Tea Cultivation

Tea is an important crop in all areas of the catchments below and adjacent to the protected areas. Tea is a high value crop that thrives on acid upland soils that are poorly suited to other crops. In terms of its environmental impact tea has advantages over other crops grown in these zones. The deep roots and ground cover provided by tea trees result in relatively good soil and water conservation. Although terracing is initially costly to construct, it is more affordable for high value cash crops such as tea than for lower value food crops. In Kenya terracing is now reported to be mandatory for anyone wishing to obtain a license to produce tea[9]. However, even in areas without fully developed terracing, the smallholder tea plantations will continue to provide high degree of catchment protection and should be actively encouraged in all areas.

A potential cause of deforestation in tea producing areas is the use of wood for drying the tea leaves. For example, tea factories of the KTDA have contributed to deforestation in some places in order to fuel this process. However, this is not an inevitable impact, and alternative fuels can be used in the drying process and timber can be sustainably harvested from dedicated managed woodlots.

As with other intensive forms of agriculture there are the usual environmental risks associated with excessive fertiliser and pesticide use. The main external input requirement for tea is

[9] Stockbridge, M. (2006). Background paper for the Competitive Commercial Agriculture in Sub–Saharan Africa (CCAA) Study. All-Africa Review of Experiences with Commercial Agriculture: Environmental Impacts.
Ovuka, M. 2000. More People, More Erosion? Land use. soil erosion and soil productivity in Muranga District, Kenya. Land Degredation and Development 11: 111-124.

nitrogenous fertiliser, which for optimum productivity needs to be applied at higher doses than for many other crops because it is the nitrogen bearing leaves that are removed when harvesting tea. Pests and diseases, however, represent less of a threat to tea than to other commercial crops and although tea productivity can benefit from the use of herbicides, it is not economically viable on smallholder plots.

Lipton and the Kenya Tea Development Agency (KTDA), supported by a grant from the UK's Department for International Development have piloted new methods for encouraging Kenyan smallholder tea growers to adopt more sustainable and more profitable farming practices. This model was seen as a success and KTDA is now committed to rolling out the Farmer Field School approach across its entire organisation[10]. This important initiative has resulted in the development of higher levels of social capital, and the programme has resulted in increased annual yields and a renewed focus on improved water and land management.

It is recommended that an important component of land management within the catchments will be a requirement for close cooperation with KTDA and the provision of active support to the Farmer Field School initiative in all relevant catchments. For example, buildings constructed at each of the Intake Weir sites could be made available for use by local communities involved with the Farmer Field School initiative, and other similar approaches to sustainable agriculture.

[10] Hiller, S., D.D. Onduru and A. de Jager (2009). Sustainable tea production: An assessment of Farmer Field Schools in Kenya. LEI Wageningen UR, The Hague

Mitei, Z. (2011). Growing sustainable tea on Kenyan smallholder farms. International Journal of Agricultural Sustainability 9(1)

8 Anticipated Impacts and Mitigation Measures

Environmental and socioeconomic impacts resulting from the proposed diversion of water for the Nairobi water supply during Phase 1 (Groundwater development) and Phase 2 Northern Collector Phase 1) will include impacts resulting from

a. Construction and development of groundwater well fields in Kiunyu then in Ruiru areas,

b. Construction of weirs, and other structures associated with intake facilities on Irati, Gikijie and Maragua Rivers, along the Northern Collector Phase I tunnel to Thika Reservoir,

c. Construction of the Northern Collector Phase I tunnel,

d. Construction of transmission pipelines and treatment works,

e. Resettlement and compensation,

f. Operation of these systems, and

g. Changes to the downstream hydrology of the river basins and downstream availability of water as a result of reduced flow in the rivers following abstraction at the intake sites.

Potential environmental impacts will result from the creation of the diversion sites and structures themselves, and from operational management of diversion sites and the impacts on downstream riverine ecosystems, including maintenance of instream and riparian habitats. Downstream impacts on riverine ecosystems are considered to be the primary environmental impacts associated with the development of these water supply abstraction sites. The most important mitigation measures are the release of good quality Reserve Flows capable of maintaining important environmental services, and at the same time capable of satisfying downstream water requirements. Additional impacts are related to a) construction and b) operation of the diversion sites themselves and associated transmission pipelines.

Of these, the major long term potential environmental and socioeconomic impacts are considered to be related to the changes in hydrology resulting in reduced downstream flows. Impacts resulting from construction, for example of intake structures and pipelines, are considered as short term impacts that will be manageable with the adoption of recommended mitigation measures.

8.1 Protected Areas and Endangered Species

The Irati, Gikigie and Maragua Rivers combine and subsequently flow into Masinga Dam in the Tana River Catchment. Downstream of the proposed intake sites, and upstream of Masinga Reservoir, there are currently no protected areas associated with the rivers from which abstraction is planned. The nearest protected area, Mwea National Reserve, is fed by rivers from Mt. Kenya. No direct impacts on protected areas are expected.

Hinde's Babbler, *Turdoides hindei*, is a threatened Kenyan endemic bird species, classified as vulnerable, occurring around some of the upper Tana tributaries. The decline of this species has been attributed largely to the clearance of scrub, on which it depends for breeding, feeding and cover. Recorded locations include the Mukuruweini valleys Important Bird Area (IBA). This lies within catchments of the Thiha and Sagana Rivers shortly to the North of the North Mathioya River.

Surveys reported by Shaw et. al (2003)[11] do not record *Turdoides hindei* as present along the rivers downstream of the planned intake sites. Indications are of a continuing decline of this species, but if conservation efforts are successful, the species may spread to areas along the North Mathioya River and ultimately to other rivers flowing from the Aberdares, in which case it may be necessary to review environmental flow releases.

The Aberdares themselves are also considered as an Important Bird Area. However, this IBA is upstream and provides almost all of the catchment area under all scenarios. Preservation of the Aberdare Forest is considered to be of critical importance for maintenance of water supplies for Nairobi. There are currently no IBAs recorded within the area affected by reduced downstream flows.

An amphibian, *Phrynobatrachus irangi*, a species of frog threatened by habitat loss, was recorded at Kimande, located between Thika dam and the Aberdare forest boundary. The IUCN Red List currently records this population as possibly extinct because of severe modification of the native habitat by local subsistence farming. The species has not been recorded in areas affected by reduced downstream flows, and none of the proposed Intake Weirs on Irati, Gikigie and Maragua Rivers are expected to have an impact on this species.

The Maragua, Gikigie and Irati Rivers each provide riparian vegetation along their length. Over this stretch of river no specific important ecosystems are identified with the exception of the riparian vegetation that provides an important natural corridor. Reduced flows will have an overall negative impact on the riparian vegetation cover, with expected long-term effects as indicated below:

A healthy riparian vegetation cover provides a number of important functions:	A degraded or reduced riparian cover:
• Supports a diversity of aquatic habitats, as well as habitats adjacent to the rivers. • Stabilises the stream banks. • Filters sediments and nutrients, which reduces pollution of the river. • Is a high productivity zone that provides food for aquatic species. • Allows selective timber harvesting, forage production and apiculture. • Shades the river, which reduces fluctuations in water temperature. • Helps to maintain the water table.	• Has fewer aquatic habitats because there is less live and dead vegetation. • Reduces the stability of the stream banks because there are fewer roots and less vegetation to hold the soil together. • Allows sediments and pollutants to enter the river more easily. • Deposits less organic matter in the stream, which means there is less food for aquatic species. • Allows more light to reach the river, increasing water temperature, promoting algal growth and reducing water quality. • Can alter the depth of the water table.

The long-term changes to riparian vegetation, combined with expected increases in clearance for agricultural activities, are expected to have a negative impact on the species diversity and populations of many bird, small mammal and other wildlife species using these resources. As a result, population numbers of some bird species are expected to decline downstream of the intake structures. Impacts are expected to reduce in intensity further downstream as other tributaries merge with the main rivers and the effective catchment area increases, providing some seasonal hydrological changes.

[11] Shaw,, P. Musina, J. & Gichuki, P. (2003). Estimating change in the geographical range and population size of Hinde's Babbler Turdoides hindei. Bird Conservation International. 13: 1–12.

8.2 Impacts from Construction

Potential negative impacts that can be expected from construction of the proposed weirs at Irati, Gikigie and Maragua, together with the construction of the Northern Collector Tunnel (Phase 1) and access shafts, and the construction of the tunnel outfall include:

- Loss of land and requirements for land acquisition.
- Soil erosion resulting from site preparation and construction activities, including from the construction of weirs, tunnels and pipelines.
- Change in local topography during site preparation/grading.
- Pollution from machinery and construction activities.
- Construction of access roads, temporary settlement and workmen's camps, and permanent offices and settlement required to maintain and run each of the weirs.
- Disposal of rock and other material excavated from the Northern Collector Tunnel and access shafts.
- Pollution from machinery and construction activities, including accidental spillage.
- Possible impacts on hydrogeology as a result of tunnelling.

Impacts from construction activities were also considered by the Howard Humphries (1998) report and those impacts remain relevant.

Due diligence and monitoring during construction activities can be expected to mitigate the majority of potential negative impacts due to construction and operational activities. Loss of land would need to be covered by compensation. This compensation will need to factor in the potential long-term loss of household income resulting from the loss of any land currently used for tea plantation.

Improvements made to existing access roads may provide benefits. Potential positive impacts include improved access enabling farm produce to gain better access to markets. Positive impacts also include local employment opportunities and the creation of a local market, although small, for materials and consumables that can be sourced locally. The overall impacts from constriction are considered to be manageable assuming that appropriate mitigation measures are adopted.

Detailed designs for the proposed weirs, intake structures and associated tunnels and pipelines are not available at this stage, but preliminary assessments and scoping of likely impacts from construction are indicated by Table 8-1Table 8-1. Similar levels of impact will be experienced by the development of each of the weirs and associated intake structures and connecting tunnels.

Construction of tunnels and associated outlets is an essential project component. Possible impacts resulting from the construction of tunnels include the creation of underground fractures with impacts on hydrogeology leading to alteration of underground drainage. In addition, the steep terrain increases the likelihood of local earth movements and landslides. Any construction activities, including tunnelling may increase the chance of landslides.

In addition, a technical committee should be established to assess potential impacts before and during construction activities, as well as to evaluate damage caused and assess required compensation. The technical committee should include environmental assessment experts and should be an integral component of the construction process.

8.2.1 Maragua Intake

Preliminary designs of intake weirs were presented in the Howard Humphries (1998) report. These designs included geographic co-ordinates enabling the proposed locations to be identified. The general arrangement of the Maragua Intake Weir was examined and compared with the current situation at that site. The proposed weir is 18.5m wide and the crest is at 2077.75m, 4.75m above the river bed level and will be constructed a short distance above the existing road bridge. Construction of the weir will require significant permanent clearance of riparian vegetation at this site. In addition, there will be permanent loss of smallholder tea, with resulting long-term impacts on household incomes for the current users of this land. There is no readily available area for disposal of excavated material.

It is considered essential that the design of the proposed weir should be modified to incorporate a calibrated triangular, or V-notch weir together with mechanisms for abstraction of different flows will provide for variable yields and at the same time will enable variable downstream Reserve Flows that preserve the integrity of downstream environments.

Figure 8-1. Proposed site for the Maragua Intake Weir

8.2.2 Gikigie Intake

The layout of the Gikigie intake weir is similar to that at Maragua. The site is shortly above an existing road bridge, which has recently been constructed (June 2011). The proposed weir

is 10m wide and the crest is at 2079.9m, 3m above the river bed level (Howard Humphries, 1998). It is expected that construction of the weir, adit, portal entrance and associated structures will result in the permanent clearance of significant areas of riparian vegetation as well as clearance of some parts of adjacent smallholder tea plantation.
As with Maragua, no area for the disposal of excavated material has been identified.
It is also considered essential that the design of the proposed weir should be modified to incorporate a calibrated triangular, or V-notch weir in order to enable variable downstream Reserve Flows.

Figure 8-2. Proposed site for the Gikigie Intake Weir

Just below the proposed site for Gikigie intake weir the river is joined by a tributary (Figure 8-3Figure 8-3). The flow from this tributary will contribute towards environmental flows downstream of the intake and abstraction. Whilst this tributary covers a smaller catchment than that controlled by the proposed weir, the flows in this tributary are currently unavailable. Relocation of the proposed Gikigie weir to below the junction of these two streams (by approximately 150 metres) would slightly increase the flow available for Nairobi water supply. However, this option would have negative impacts on downstream environmental flows and compensation flows. Flows from this smaller tributary will contribute towards improved downstream environmental flows. Specifically these flows will be enhanced by an increased variability of downstream flows, including occasional high flow pulses.

The preliminary designs for the Gikigie Intake weir given in the Howard Humphries (1998) report indicate fish ponds adjacent to the site of the proposed weir. These ponds will need to be rehabilitated and or reconstructed following the completion of construction and tunnel excavation activities at Gikigie. At the same time there is also the opportunity to expand the ponds and/or increase their number, and this can be seen as part of the compensation available for the local community.

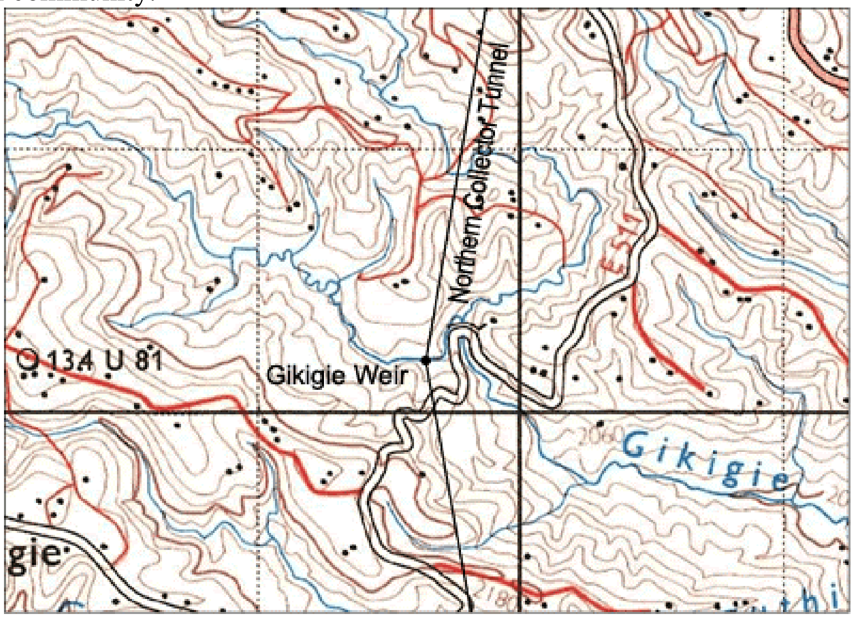


Figure 8-3. Location of the Proposed Gikigie Weir

8.2.3 Irati Intake

Problems were identified with the location of the proposed Irati weir, intake and shaft. The position indicated by the geographic co-ordinates presented on the preliminary designs in the Howard Humphries (1998) report, when overlaid on the 1:50,000 scale map, show that the two tributaries join at the same spot where the plan indicates the main weir is (Figure 8-4Figure 8-4 site A). Combined flow from these two tributaries has been used in the modelling of available water sources on the Irati for diversion to the Nairobi water supply. There is no indication of any tributary in the preliminary design drawing. The Howard Humphries report states that "The river weir is 14.5m wide and the crest is at 2008.9m, 900mm above the river bed level." Locating the weir on the 50,000 map using the co-ordinates given on the preliminary design, the elevation at the identified site of the weir is between the 2,100 and 2,120 metre contours. Furthermore, whilst the main text in the Howard Humphries report states 2,008.9 metres, the preliminary design drawing indicates 2,108.9 metres (2008.9 is now assumed to be a typing error).

The preliminary design drawing, however, clearly indicates a small island at the site of the weir. About 500 metres downstream of the road crossing there is a small island of the same shape. The elevation at the site of this small island is 2,107 metres (using Aster digital elevation data). This site is below the junction of the two tributaries (Figure 8-4Figure 8-4 site B) and may have been the intended site for the Irati Weir. However, this is about 500 metres downstream of road crossing and a more likely site for the Irati weir is now considered to be closer to the road crossing (Figure 8-4Figure 8-4 site D).

Assuming the modified location for Irati Weir, there will be no requirement to relocate, or modify the road crossing the Irati River in order to accommodate the weir and associated structures..

Construction of the weir will require permanent clearance of riparian vegetation at the site. However, it is likely that there will be no requirement for clearance of permanent crops such as tea, as long as the required facilities adjacent to the Irati intake weir can be located appropriately so as to avoid areas covered by tea plantation. Crops grown at or immediately adjacent to the site of the weir are annual crops such as maize, brassicas and other crops used for household consumption, whilst the land is also used for grazing livestock. Compensation for the loss of the productive agricultural land will be required for the households using these areas.

As with the Maragua and Gikigie intakes, no area for disposal of material excavated during construction of the Northern Collector tunnel has been identified. It is also considered essential that the design of the proposed weir should be modified to incorporate a calibrated triangular, or V-notch weir.

An important consideration is that the smaller of the two tributaries that form the Irati at this point also serves as one of the sources of the Kigumo Rural Water Supply Scheme (Figure 8-4Figure 8-4 site C). Consideration should be given to the rehabilitation and rebuilding of the Kigumo water supply intake so that this important rural water supply is incorporated with the overall plans for Irati Weir and Intake.

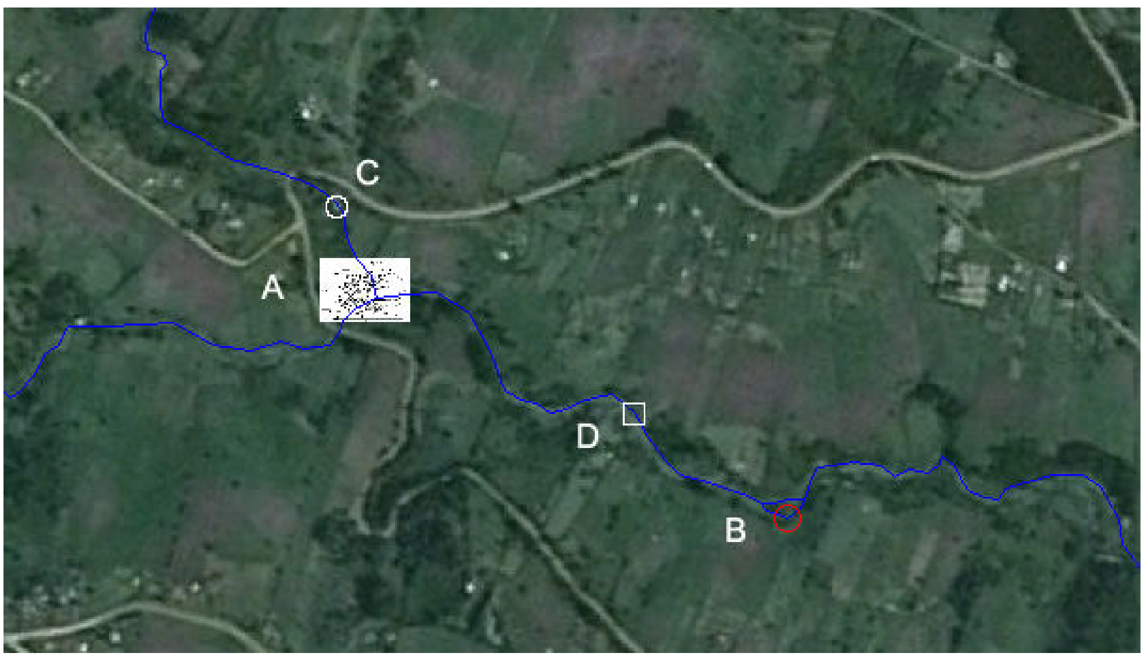


Figure 8-4. Location of proposed Irati Weir and Intake Shaft:

A. Site identified by co-ordinates given in Howard Humphries (1998) report, B. Site of island in river (red circle); C. Intake for Kigumo Rural Water Supply Scheme (white circle); and D. Proposed site for the Irati Weir.

8.2.4 Outlet Works

The purpose of the tunnel outfall works above Thika Reservoir is to release the water from the Northern Collector tunnel safely without erosion of the river banks. The river bed level is 5 metres below the intended outfall. The outfall structure will be founded on rock so as to minimise potential erosion. It will be necessary to construct an access track from the main road to the outlet site.

The site of the proposed outlet works is largely covered by trees, with some relatively open grassland adjacent to this area. This is surrounded on all sides by tea plantation (Figure 8-5Figure 8-5).

Clearance of the natural riparian vegetation will be required. Clearance of tea will be necessary for parts of the tunnel outlet structures, and also for construction of the access road and any associated buildings required for administration and running of the site.

Increased flows along this short stretch of the river between the outlet works and Thika reservoir are likely to result in increased erosion of river banks, especially in areas where riparian vegetation cover is cleared as part of the construction process. Measures to control river bank erosion should be installed at these sites.

Figure 8-5. Proposed site for Outlet Works above Thika Reservoir, showing riparian vegetation and surrounding tea plantation.

8.2.5 Excavated Material from the Northern Collector Tunnel

Construction activities will result in significant volumes of excavated material derived from the rock excavated from the tunnels. No areas for "spoil dumps" have been clearly identified. Disposal of the material from the tunnel in dumps will have inevitable negative impacts. The resulting areas will remain bare for several years and they are likely to become colonized by invasive species. Irrespective of the location of sites that may chosen for disposal of excavated material, they will most likely result in loss of land that could otherwise be used for productive purposes.

It is recommended that no permanent "spoil dumps" are used. It is suggested that instead of considering the excavated material as spoil, requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material, including the making of bricks for buildings.

The most critical area for disposal of excavated material is likely to be near to the Gikigie intake structure, with up to 135,000 m^3 of excavated material (assuming a 1.8 bulking factor). For Gikigie this may require 11,200 lorry loads to remove the material (assuming 10 m^3/truck or about 20 tonnes per truck load). Over a 12 month construction period, this would be up to about 40 trucks per day or as many as 80 per day if trucks with a 10 tonne capacity are used. The Kaanja access adit, if constructed, would also require a large storage area (81,000 m^3 assuming 1.8 bulking factor) if stored on-site. At the Maragua intake, the storage volume required would be 54,000 m^3 (with 1.8 bulking factor). At the Makomboki outfall, a significant quantity of material will be extracted. The presence of tea plantations at the Makomboki outfall will require careful design of an access track for removal of all of this material for disposal elsewhere. Similarly, the steep slopes of the terrain and the tea plantations adjacent to all of the other sites also indicate that there should be no permanent on-site storage of excavated material.

It is recommended that on-site storage of excavated material should be minimized and that only temporary storage sites should be constructed near each access site. It is recommended that the excavated material is transported away from the sites at a rate similar to the rate of extraction. The emphasis should be for the material to be transported for either temporary or permanent storage at suitable sites elsewhere. These sites should be accessible to potential users of the excavated material.

On-site storage of excavated material will require the construction of fully bunded structures to contain all of the excavated material so as to prevent erosion and siltation in the rivers, constructed at least 40 m buffer zone between the bunded storage area and the edge of the river. Excessive sedimentation of the rivers can cause flooding, require expensive clearing or channel maintenance, or reduce the capacity of downstream water storage units. It may also damage valuable riparian vegetation and degrade downstream agricultural areas situated alongside or close to the rivers or in floodplains.

If temporary and/or permanent storage areas are required for disposal of the excavated material, the use of abandoned quarries should be considered. Plans will need to be drawn up for disposal, as part of quarry rehabilitation measures, of that portion of the excavated material which cannot be reused. As indicated above, transport of the excavated material to selected abandoned quarry sites will require a significant number of lorry loads on a daily basis. It is therefore likely that the rural roads that provide access to these sites will require to be upgraded and/or regularly maintained in order to provide access for these transport vehicles as well as for all of the normal traffic on these access roads. In particular, the regular access by transport related to tea harvesting is considered to be of critical importance. The preferred outcome for the management of all excavated material generated by excavation of the Northern Collector tunnel is the reuse of all spoil material that is generated, for example for engineering purposes, for use as building material, or for road repair, construction and maintenance.

8.2.6 Transmission and Distribution Pipelines

The installation of transmission and distribution pipelines will result in potential disturbance to natural habitats, to agricultural land and to communities. Habitat restoration and maintenance will be required after pipeline construction is completed. Most of the pipelines will be in settled areas that are already environmentally altered and land will need to be acquired. Positive impacts from pipeline construction include the creation of job opportunities, as well as the potential for improved habitats for local wildlife species along the wayleave if this strip of land is managed appropriately.

Construction of pipelines can be expected to include the following negative impacts:

- Impacts on local flora and fauna as a result of clearing vegetation along the pipeline. Short-term if all mitigation measures are carried out. Impacts will be long-term if habitat restoration is not carried out.
- Increased erosion as a result of excavation for the pipeline, as well as potential water quality impacts, especially where the pipeline route crosses streams or other drainage lines.
- Soil erosion and potential pollution of rivers or streams crossed by the pipeline.
- Land acquisition for pipeline wayleave, loss of productive agricultural land and/or building land, together with associated needs for resettlement and compensation requirements.
- Noise generation and vibration resulting from use of heavy machinery during construction.
- Temporary construction camps, including generation waste that will require disposal.
- Disposal of solid waste material from excavation and earthworks.
- Impacts on roads where transmission pipelines cross roads.

Mitigation measures include:

- A technical committee, including environmental assessment personnel, should be established to assess the damage caused and assess required compensation.
- Incorporation of measures in the design and routing of pipelines that require less vegetation clearance.
- Compensatory plantation of trees and other vegetation should be carried out at the rate of a minimum of five trees planted for every tree cut. All trees should be indigenous species.
- Prepare and implement an erosion control plan.
- The exact pipeline route will need to be delineated well in advance of any construction activities and list of affected people, as well as specific habitats, should be prepared.
- A Resettlement Action Plan should be prepared. Involuntary displacement should be avoided.
- Loss of crops, as well as trees and other natural resources should be compensated.

- Compensation of affected land and property assets lost should be provided. Full cost of compensation, relocation or resettlement should be provided. Compensation will need to be provided in lieu of loss of earnings.
- Provision of new or modified infrastructure to compensate for loss or impacts to existing facilities (including roads, schools, health facilities, market areas etc.).
- Traditional rights should be protected.
- Employment opportunities should be given to the local people.

Table 8-1: Impacts related to pipeline construction and operation

Issues	Nature of Impacts	Mitigation Measures
Land clearance	Impacts on local flora and fauna as a result of clearing vegetation along the pipeline. Short-term if all mitigation measures are carried out. Impacts will be long-term if habitat restoration is not carried out.	• Baseline surveys • Habitat restoration • Monitoring
Soil erosion	Increased erosion as a result of excavation for the pipeline, as well as potential water quality impacts, especially where the pipeline route crosses streams or other drainage lines.	• Erosion control plan • Due diligence during construction
	Soil erosion and potential pollution of rivers or streams crossed by the pipeline.	
Loss of land	Land acquisition for pipeline wayleave, loss of productive agricultural land and/or building land, together with associated needs for resettlement and compensation requirements.	• Compensation for loss of land and for loss of household income • Resettlement Action Plan
Workmen's camps and Settlements	Noise generation and vibration resulting from use of heavy machinery during construction.	• Careful planning and location of campsites • Provision of adequate sewage and waste disposal facilities • Provision of adequate services • Provide local employment
	Temporary construction camps, including generation waste that will require disposal.	
	Disposal of solid waste material from excavation and earthworks.	
Access roads	Impacts on roads where transmission pipelines cross roads.	• Include in detailed design
Access for maintenance	Long-term access to the pipelines will be required for routine checking and maintenance. Assuming that most of the pipeline length is buried with limited surface structures, the overall impacts will be relatively low.	• Careful location of pipelines
Leakage	Leaks are likely to occur along tunnels, along transmission and distribution pipelines, and at	• Regular monitoring and maintenance

	treatment works. Leakage may result in health risks, e.g. Malaria, Cholera and other water related diseases.	• Early leak detection reduces possible public health risks
Local water supplies	Consideration should be given to ensure that all communities traversed by the pipelines are fully provided with piped water supplies, as a priority.	• Provide adequate local, rural and urban water supplies along pipeline routes

8.3 Impacts from Operation

Impacts from operation of weirs are listed in Table 8-3Table 8-3. Primary environmental impacts resulting from operation of the intake weirs and Northern Collector Tunnel are related to the significant change in downstream hydrology. These result from changes to water flow patterns, changes in quantity (in particular the loss of flood events), and also from a deterioration in water quality. Changes in water quality are themselves a direct response to the changes in flow. In addition, the normal or base flows will, after installation of the intake weirs, change to the flows similar to those currently classified as "extreme low flows", or to the lower range of flows classified as low flows, or base flows. .

The provision of adequate downstream environmental flows, as a component of Reserve Flows, is considered to be essential for all rivers, as described above under "Downstream Reserve Flows". Similarly, provision of adequate compensation flows is viewed as being critically important.

An important consideration is the cumulative impact arising from the combined operation of all three weirs with release of downstream Reserve Flows. Cumulative impacts include the following factors (see also section 6 on Cumulative Impacts):

- Short periods or single days with zero flow, preceded and/or followed by further periods with extreme low flow.
- Reduction in the flow reaching Masinga Reservoir (by an estimated 3.17% on annual basis).
- Less flow available for use in current and future agricultural activities, especially for use during dry seasons, in order to provide food required by the increasing population of Nairobi.

Catchment protection is viewed as an important task during operation of the intake weirs. Careful planning and management of land use in the catchments will limit the inflow of sediments and excessive nutrients. In particular the following measures are considered to be important:

- Complete protection and careful management of the Aberdare Forest Reserves to ensure continued catchment protection. Any felling of trees within the forest reserves should be kept to a minimum and if carried out must be confined to small areas surrounded by intact forest.
- Provision of active support to the KTDA Farmer Field Schools initiative mentioned above will be a positive approach and one that is likely to result in improved water and land management within catchments, as well as improved social capital and sustainable farming practices.

Weirs will trap some sediment. Reduced downstream flows will also result in a reduced sediment transport. Sediment transport is an important function of river flows, and this serves to maintain aquatic habitats and downstream environments. Changes to sediment transport will have inevitable impacts on downstream systems. Sediment will also not be available for riparian vegetation, and for downstream agricultural systems, some of which may partly depend on some of the alluvium deposited by flood events. The design of the proposed weirs should allow for sediment release.

Mitigation is possible through the release of good quality Reserve Flows from all structures, including environmental flows and compensation flows. However, it is important that flows and downstream demands are comprehensively monitored and that when abstraction is not required, no water is diverted unnecessarily for Nairobi water supplies and it is allowed to flow downstream in the source rivers. Similarly, when monitoring indicates that downstream requirements may be in deficit, abstraction volumes will need to be adjusted accordingly.

The use of gravity fed pipelines for distribution of water from Thika Reservoir is important. This will reduce the overall requirements for pumping, and will have long-term environmental benefits as a result of reduced use of energy, as well as reduced operating costs. Similarly, priority should be given to the maximum use of gravity fed pipelines elsewhere in the distribution network.

8.4 Impacts and Mitigation Measures

Mitigation measures are aimed at eliminating, offsetting, or reducing adverse environmental impacts and may have a number of different actions or objectives, including:

- Avoidance: Avoiding activities that could result in adverse impacts; avoiding certain resources or areas considered to be environmentally or socially sensitive.
- Prevention: Measures aimed at preventing the occurrence of negative environmental impacts and/or preventing activities that are likely to have harmful environmental and social impacts.
- Preservation: Preventing any future actions that might adversely affect an environmental resource. This may for example be achieved by extending legal protection to selected resources.
- Minimisation: Limiting or reducing the degree, extent, magnitude or duration of adverse impacts. This can for example be achieved by scaling down, relocating, or redesigning individual elements.
- Restoration: Restoring affected resources to an earlier (and possibly more stable and productive) state, typically a ‘pristine’ condition.
- Compensation: Creation, enhancement, or protection of resources at an alternative suitable and acceptable location, or compensating for lost resources. The sustainability of compensation measures should be considered, e.g. the loss of future household income due to the loss of productive agricultural land may not be sustainable from a one-off compensation payment but could be offset by activities designed to provide long-term and improved sources of household income.

Table 8-2: Impacts due to Construction of weirs, intake structures and tunnels

Issues	Nature of Impacts	Mitigation Measures
Loss of land	Land will be acquired to enable construction of and provision of adequate buffer zones round weirs, treatment works, pipeline wayleave, workmen's camps and working areas. Loss of smallholder tea plantation in particular will lead to long-term changes in household incomes.	• Compensation for loss of land • Compensation for loss of household income
Change in land use	Change in land use from one dominated by natural riparian vegetation with adjacent tea plantations, to a cleared area with weir, intake structures and associated infrastructure. Clearance of riparian vegetation will disrupt natural wildlife corridors.	• Minimize clearance of natural vegetation • Creation of wildlife corridors
Access roads	Access roads will be required to enable construction, as well as for subsequent system operation. Maragua and Gikigie can largely use existing access, but new access tracks will be required for Irati, tunnel outfall and adits.	• Compensation for loss of land
Soil erosion and Siltation	Combined with the steep terrain, exposed earthworks required for site preparation and construction are likely to result in increased soil erosion. Siltation created during construction will pass downstream, with potential negative impacts on the environment and on water quality.	• Erosion control measures • Due diligence during construction
Pollution	Construction activities will create air, dust and noise pollution. Contamination from wastes and oil/fuel spills may occur. Contamination from dust, and from oil/fuel spills, may spread to adjacent agricultural land, e.g. tea, thereby significantly reducing its value.	• Pollution control measures • Due diligence during construction
Solid waste disposal	Construction activities will result in significant volumes of excavated material at some locations, especially from tunnels. Disposal of this material may have a negative impact unless carefully planned, or used for other activities such as road construction, or building materials. Instead of being classified as "spoil" it should be seen as a potentially useful raw material.	• Careful planning of disposal of excavated material • Use excavated material for road repair & construction and as raw material for other construction

Workmen's camps and Settlements	Camps required for construction workers may overburden local services. Problems may occur in relation to disposal of waste and sewage, and surface waters may be contaminated, with associated dangers to public health. Induced settlement is likely to occur as a result of construction. This may be beneficial to local communities, but will also stress local resources, including water supplies and household fuel. There may also be health risks and increased requirements for health services. The construction phase may also provide local employment opportunities, but these must be scheduled to avoid peak tea picking activities.	• Careful planning and location of campsites • Provision of adequate sewage and waste disposal facilities • Provision of adequate services • Provide local employment
Hydrogeology	Tunnelling may result in changes to underground drainage as a result of underground fractures.	• Detailed investigation during construction
All issues	A technical committee should be established to assess potential impacts before and during construction activities, as well as to evaluate damage caused and assess required compensation. The technical committee should include environmental assessment experts.	

Table 8-3: Impacts due to Operation of Weirs

Issues	Nature of Impacts	Type of Impact and Mitigation Measures
Change in downstream flow in Irati, Gikigie and Maragua Rivers. **Including Cumulative Impacts from the combined changes in downstream flow of all three rivers.**	**Change from a natural flow to a flow similar to a permanent low flow, extreme low flow or drought condition as a result of:** **a) diversion of water at weirs, and** **b) retention of this water in Thika Reservoir** **Loss of downstream water resources, and reduced ecosystem services in the impacted rivers.** **Loss of vegetation and wildlife dependant on these water resources.** **Reduced potential for settlement and agricultural development downstream.** **Changes in the water table as a result of reduced flows in the rivers.** **Reduced water quality as a result of downstream flows being similar to extreme low flows.**	• Long-term. Permanent. • High impact without adequate EFR • Low impact if good quality Reserve Flows are adopted and managed • Release Reserve Flow adequate to sustain all required downstream water resources • Establishment of a comprehensive monitoring programme and technical committee

Issues	Nature of Impacts	Type of Impact and Mitigation Measures
Diversion of flow from Irati, Gikigie and Maragua Rivers to Thika reservoir	A dam safety assessment may be required as the project includes water intake into the Thika Reservoir.	• Conduct dam safety assessment
Reduced flows available for use by households	**Reserve flows include Compensation flows and there will be a need for a complete inventory of required compensation flows, together with a need for ensuring that all households are included in rural water supply schemes.**	• Inventory of all needs • Release of adequate compensation flows • Household water supply schemes for all
Periods with very low or zero flow	**Some periods with zero flow and very low flow are predicted to occur further downstream. Reserve Flows will need to be monitored and adjusted accordingly.**	• Release Reserve Flow adequate to sustain all required downstream water resources
Change or loss of habitat downstream as a result of changed hydrological regime. Including cumulative downstream impacts.	**Loss of riparian vegetation.** • **Reduced stability of stream banks due to fewer roots and less vegetation binding the soil.** • **Potential increase of pollutants entering the rivers.**	• Long-term impact • High impact without EFR. Low impact if a good EFR is put in place
Effects of reducing the flow of nutrients downstream	**Reduced nutrient availability in downstream areas may result in a reduction in productivity of downstream systems, including cultivation in alluvial areas downstream.**	• Long-term. Permanent • Mitigation possible through EFR and sediment transport enabled by flood events
Trapping of sediments	Nutrients captured in Thika Reservoir, especially those that tend to bind with fine sediments, will no longer be available to downstream systems and may result in eutrophication in the reservoir.	• Incorporate sediment release capabilities in weirs. • Incorporate sediment release capability in Thika Reservoir.
Sedimentation at interface between inflowing stream and the reservoir	Unless sediments are filtered out before entering the Northern Collector tunnel, increased sediment deposits will form at reservoir entrance.	• Long term. Low impact. • No mitigation other than removal of accumulated sediments.

Issues	Nature of Impacts	Type of Impact and Mitigation Measures
Change in aquatic environments and reduced potential for fish migration, and movement of other aquatic species	The potential for passage of fish upstream will need to be assessed in detail at the detailed design stage of each structure, to ensure survival of fish species, including endemics and potentially threatened species.	• Designs for fish ladders need to be reviewed and fully incorporated in all proposed Intake weirs.
Power lines	**The presence of power lines creates a potential hazard to larger bird species.**	• Mitigation thorough appropriate design of power lines and transmission towers.
Access roads	Improvements to existing access roads and development of new access tracks open up new areas to development and if carefully planned with inputs from local communities can provide local benefits. Material excavated from the tunnel can be used for road maintenance or rehabilitation.	• Low impact if mitigation measures are adopted. • Mitigation through careful routing of access roads.
Settlement resulting from project operation	**In addition to operational staff, induced settlement is likely to occur in the surrounding area, creating potential stress on local resources and facilities, including fuelwood.**	• Planning of settlements and provision of fuel resources.
Impact from presence of pipelines	**Long-term access to the pipelines will be required for routine checking and maintenance. Assuming that most of the pipeline length is buried with limited surface structures, the overall impacts will be relatively low.**	• Careful management and location of pipelines.
Leakage from pipelines and contamination of supply lines	**Leaks are highly likely to occur along transmission and distribution pipelines, and possibly at treatment works. Contamination of supply pipes may also occur at these sites. Leakage may result in health risks, e.g. Malaria, Cholera and other water-related diseases.**	• Regular monitoring and maintenance is essential. • **Early detection of leaks reduces the possibility of public health risks.**

Issues	Nature of Impacts	Type of Impact and Mitigation Measures
Public health risks	**Reduced water quality as a result of reduced flows will result in increased health risks for downstream communities or households dependant on untreated river water.** **A change in faecal bacterial concentrations and waterborne pathogens as a result reduced flows and from inflow of contaminants from upstream is likely and needs to be monitored.**	• A programme for regular monitoring of pathogens, and assessment of risks from waterborne diseases.
Inflow of effluents and pollutants from upstream sources	**Inflow of dissolved effluents and pollutants will have an impact on water quality with potential impacts on human health.** **Inflow of solid wastes and pollutants are likely to have a negative impact on the natural environment.**	• Regular water quality monitoring. • Active management and clearance of solid wastes may be necessary. • Sewage and effluent collection and treatment facilities for all habitation within catchment areas.
Effects from changes in groundwater levels	**Changes in local groundwater regime are possible as a result of reduced downstream flows.**	• Long-term. • Uncertain impact.
Impacts due to proposed treatment works	**Use of hazardous chemicals, including chlorine.** **Agricultural chemicals resulting from agricultural activities in catchment areas may also require additional or special treatment of water before distribution.**	• Proper procedures for use and disposal of chemicals. • Adequate Reserve Flows for dilution of wastes, and sludge from treatment. • Catchment management.

Issues	Nature of Impacts	Type of Impact and Mitigation Measures
Risks from Seismic Activity	**The proposed Northern Collector Tunnel is in an area with recorded seismic activity. Data are recorded at the seismic station at** Kilima Mbogo**.** **Seismic activity could have an impact on tunnels, as well as the existing Thika Reservoir.** **Annual inspections of the** Northern Collector tunnel **should be conducted, and there should be a contingency plan to be followed in the case of earthquakes.**	• Risks will need to be fully assessed as part of detailed design. • The tunnel **should be issued with an annual compliance certificate that it is seismically sound.**

8.5 Aquatic and Riparian Environments

8.5.1 Impacts on Aquatic and Riparian Species

Endemic and Introduced Fish Species

Weirs, dams and other structures along a river or stream will have inevitable impacts on fish species living in the rivers. In particular, obstacles to upstream movement or migration need to be avoided and, where present, fish ladders or other means of passage need to be provided. The passage of fish upstream through the diversion structures is considered in the Howard Humphries (1998) report, which states that "Inlet and outlet portal and shaft design will need to take into consideration free movement of fish species". The Howard Humphries report included considerations for the passage of migratory fish species on all weirs for the Northern Collector tunnel. For example, the intake for the Irati River indicated that the river diversion weir and compensation flow conduit will provide passage to fish at all states of river flow. On the Gikigie River the proposed design for the compensation flow conduit provided a potential passage for migratory fish under normal flow conditions. A short cascade would enable fish to enter the flume built into the conduit and from there swim through a short length of 250 mm diameter pipe. When the river is in flood, the 600 mm diameter overspill weir discharge pipe would also be passable.

However, the Howard Humphries (1998) report only appears to consider trout when considering environmental impacts on fish species. The trout, although present in some of the rivers flowing from the Aberdares, is an introduced species (and can be reintroduced as and when considered necessary). Of much greater concern are the indigenous species of fish, including small *Barbus* that may be present in the upper reaches of these rivers and streams. For example, *Barbus thikensis* is present in the Chania River, the original type locality is the Thika River, and is recorded in fast flowing water typical of the upper reaches of the rivers under consideration as sources for the Nairobi water supply. A wide range of other fish species have also been recorded, including *Alestes*, *Barbus*, *Clarias*, *Labeo*, *Sarotherodon* (Tilapia), and others, some of which are endemic to the catchments. Two *Labeo* species found in the Tana, namely *Labeo cylindricus* and *L. gregorii* both migrate into upstream tributaries at the time of the first floods. Reduction in flows and the resulting hydrological alteration will have inevitable long-term negative impacts on such species.

It is considered important that designs for fish ladders are reviewed, are updated, and are fully incorporated in the final designs for all proposed weirs, and that these are combined with the release of downstream Reserve Flows. Designs must be suitable for the passage of local endemic fish species. The potential for passage of fish upstream through the planned diversion structures will need to be assessed in detail at the detailed design stage of each diversion structure in order to ensure survival of the local fish species, including endemics and potentially threatened species.

It is recommended that the designs for fish ladders are based on a combination of "pool passes" and "nature-like bypass channels".

The principle behind "pool passes" is the division of the height to be passed into several small drops by forming a series of pools. The passage of water from one pool to another is either by surface overflow, through one or more submerged orifices situated in the dividing wall separating the pools, or through one or more notches or slots. The "nature-like bypass channel", being similar to a natural stream, is a waterway designed for fish passage around the obstruction. The function of a "nature-like bypass channel" is restorative in that it replaces a portion of the flowing water habitat which has been lost due to impoundment by the intake weir. Both of these channels are characterised by a low gradient along their full length.

It is recommended that the downstream entrance to the artificial channel, either “pool passes” or “nature-like bypass channels”, be located as close to the obstruction as possible. Given the low gradient required along their length, for reasons of limited space it is sometimes difficult to position the entrance immediately below the obstruction, which means it may need to be placed further downstream. This may restrict the efficiency of these passes so it is strongly recommended that the entrances should be placed as close to the bottom of the weir as possible.

Invertebrates

Invertebrates play a major part in river functioning, whilst their forms, ecological and habitat requirements are diverse. They are responsible for retaining and breaking down organic material, recycling minerals and nutrients, and contributing to energy processing in the river at different trophic levels. Most benthic invertebrates are detritivores, although some are herbivores and some are carnivores. Other possibly lesser effects include the transport of organic material into and out of the river and structural activities such as case building and gluing or enmeshing particles of silt and sand. Burrowing invertebrates, such as worms, are also important in aerating sediments and releasing nutrients.

Changes to flow regimes can have significant impacts on invertebrate communities, and may result in long-term changes to ecological processes. Adequate provision of environmental flows, including periods of low flow, freshets and high flows, will be important in helping to maintain invertebrate communities.

Vegetation is a dominant part of most riverine ecosystems, where it fulfils a number of critical functions. This is the case along all of the riverine environments downstream of the proposed intakes and reservoirs. Aquatic and riparian vegetation stabilise river channels, river banks and floodplains; contribute towards the attenuation of floods (recharging local groundwater resources); influence water temperature and quality; and provide habitat, refuge and migration corridors for terrestrial and aquatic fauna. The structure, composition and overall condition of the vegetation determine the degree to which it is involved in ecosystem functioning. The vegetation also provides many resources used by man, including food, and has an aesthetic component that is also valued by man. Aquatic and riparian vegetation is adapted to the full range of flows experienced by the relevant stretch of river. Modification of the flows, for example changing from natural flows to a flow regime that is equivalent to a permanent low flow, “flatlining”, drought flow or extreme low flow, can be expected to have long term negative consequences, especially for riparian vegetation and communities that are adapted to a range of different flow regimes.

The potential impacts on the different components of aquatic and riparian ecological communities emphasize the importance of maintaining adequate downstream Reserve Flows, including the full range of periods of extreme low flows, low flows, high flow pulses, and periods with high flows.

8.5.2 Impacts on Diseases

Permanent low, or extreme low flows, are known to have an impact by increasing the populations of a number of disease vectors. This includes the invertebrate hosts of Malaria, Schistosomiasis (Bilharzia) and Fascioliasis (liver fluke disease) as well as **faecal bacterial contamination and associated waterborne pathogens**.

FOR MALARIA MOSQUITOES, FLOW RATE IS IMPORTANT. An increase in the frequency of Low Flows will tend to increase vector populations in downstream environments. Mosquito larvae have no way of combating stronger currents and therefore are swept out of riverside pools and shallow areas by short periods of higher flows and short high flow pulses.

Retreating flood waters may however create new pools and breeding opportunities for mosquitoes, and the short duration of the larval stage means that short pulses of higher flows generally need to be repeated within 10 days. Regular flushing, for example at weekly intervals from intake weirs, will result in significant reductions in populations of the mosquito vectors in downstream areas and in reduced potential for malaria transmission.

In Kenya, both human urinary Schistosomiasis caused by *Schistosoma haematobium*, and ruminant Schistosomiasis caused primarily by *S. bovis* are common. These two species are closely related and are often sympatric, because both species depend on particular species of freshwater snails as intermediate hosts. Both species are transmitted in Kenya by members of the *Bulinus africanus* group and a number of other *Bulinus* species. The bodies of water that potentially harbour *Bulinus* and their associated Schistosomes are often man-made impoundments, slow flowing rivers, or small seasonal streams that are used intensively by both humans and livestock, thus bringing together all the required hosts of these Schistosomes. Villages without piped water are marked by higher initial prevalence of *S. haematobium* infection[12]. The snail hosts of Bilharzia, are likely to increase in number under situations dominated by low flows or extreme low flows.

Fascioliasis, a zoonotic disease of domestic herbivorous animals such as sheep, cattle and goats, which are the definitive hosts, is caused by infection with the liver fluke, *Fasciola hepatica* and *F. gigantica*. Massive infestation is common in sheep and bovines, and it can also occur in humans. Eggs are discharged with faeces and embryos develop in water and hatch into larvae which invade and develop in intermediate snail hosts. Cercariae are released from the snail and encyst aquatic vegetaton or other surfaces. Infection is acquired by livestock, or humans, eating the contaminated vegetation. Although animals may be able to support large worm burdens without developing serious disease, *Fasciola* spp. can cause severe, even fatal disease in humans. Flushing of streams with high flow pulses is an effective method of control.

Snails are susceptible to higher flow pulses and are likely to be washed away. Additionally stronger currents are thought to reduce breeding success as snails expend more energy attempting to resist dislodgement. Flushing of streams with high flow pulses is considered an effective method of control.

There are also a large range of water-related microbial infectious diseases, including pathogens transmitted by range of different routes. Similarly, a change in faecal bacterial concentrations and associated waterborne pathogens as a result of runoff and inflow of contaminants is possible and needs to be monitored. While water quality affects transmission rates of many water-related diseases, changes in water flow or water quality, which can influence the population dynamics of vector species that transmit infectious diseases and intermediate hosts for microbial pathogens, also influence the prevalence and transmission dynamics of infectious diseases.

The reduced flows resulting from upstream abstraction will inevitably reduce the potential for flushing of contaminants downstream, for example during high flow pulses. This will increase the concentrations of and potential dangers from bacterial concentrations in rivers, with associated risks when untreated river water is used, for example by rural households. Similarly, the potential negative impacts on vector control and disease transmission resulting from significantly reduced downstream flows further

[12] Muchiri E.M., Ouma J.H. & King C.H.(1996). Dynamics and control of *Schistosoma haematobium* transmission in Kenya: an overview of the Msambweni Project. Am J Trop Med Hyg. 55(5 Suppl): 127-34.

reinforces the requirements for a Reserve Flow that includes regular high flow pulses and other periods of higher flows.

Mitigation

It is recommended that regular higher flow periods are released from each of the intake weirs when suitable upstream flows are available, and that this practice is adopted as a standard management practice. These higher flow releases may for example be released during periods of high flow pulses, small floods and large floods. Consideration should also be given to the release of higher flow periods using parts of the normal base flows.

8.5.3 Interbasin Transfers

Environmental impacts related to interbasin transfers include fish and wildlife habitat changes and water quality changes. Impacts on the Athi basin are not expected to be significant as the rivers on which the proposed Northern Collector tunnel Phase 1 intakes are situated (Irati, Gikigie, Maragua) are connected to tributaries of the Tana. All negative impacts resulting from reduced downstream flows will therefore occur in the Tana basin. Changes in aquatic habitats will primarily result from hydrological changes discussed above under environmental flows.

Transfers of water will take place from these rivers, via transfer to Thika Reservoir, and ultimately to locations within the Athi basin. It is therefore expected that increased consumption will result in increased waste water flowing into the Athi River. The impacts of this increased flow into the Athi will largely depend on the quality of the waste water treatment process.

Water in the Thika Reservoir will be from the combined catchments of Thika, Irati, Gikigie and Maragua Rivers. Catchment management in all of these basins will therefore have an impact on water quality in Thika Reservoir.

Transfer of flow from upper Tana tributaries to the Athi River basin could potentially result in some fish species present in the upper Tana basin being transferred to the Athi. However, because of the passage through filters and pipelines, and the subsequent treatment of the water, this is considered to be unlikely.

Socioeconomic impacts related to interbasin transfers include the ability of the source basins to supply water to established and future users of the water resources, and economic and operational impacts on hydropower generation. Interbasin transfers will result in reduced downstream flows in rivers flowing into the upper Tana and ultimately into Masinga reservoir. In addition to impacts on hydropower potential, the reduced inflows to Masinga reservoir may have some impact on the potential for development and management of Reserve Flows on the Tana, including environmental flows, targeted at downstream communities and environments on the Tana River.

As a result in the changes in availability of water resources in areas downstream of the interbasin transfers, there may also be changes to the ability of a region to attract or sustain economic development.

8.6 Analysis of Alternatives

A "No Project Option" Alternative was considered not to be viable. The "No Project Option" Alternative would imply that the status quo is maintained and no additional water supplies are developed for Nairobi and adjacent satellite towns. From an environmental perspective and particularly from a socio-economic perspective the No Project Alternative is not considered as a suitable solution for affected communities and for Kenya as a whole.

With the exception of groundwater development, all the available surface water sources are derived from rainfall within catchments on the Aberdare Range and adjacent areas. As indicated by **Table 8-4**~~Table 8-4~~, the Surface Water Resource available from existing sources are primarily from rivers with catchments that include parts of the Aberdare Range. If continued development of water sources from the Aberdares is not available, projected increase in the population of Nairobi and adjacent satellite towns will inevitably result in severe water shortages in these areas.

Table 8-4: Yield of Existing Water Sources

Source	Yield (m^3/d)	Remarks
Sasumua Reservoir	57,000	Existing
Chania River / Mwagu Intake	104,000	Existing
Ruiru Reservoir	21,000	Existing
Kikuyu Springs	4,000	Existing
Ndakaini Dam (Thika 6)	225,000	Existing (70 Mm^3 Storage).
Groundwater (Private & NWSC Boreholes)	45,000	Estimated Contribution
Total	456,000	

Source: Water Sources Options Review (August 2011)

A number of sources have been proposed to supplement the existing sources to supply the main schemes supplying Nairobi City. The expected yields as assessed by previous studies were checked and refined in the present study as presented by the Water Sources Options Review Report (August 2011) of the Feasibility Study and Master Plan for Developing New Water Sources for Nairobi and Satellite Towns. Taking account of population and water demand projections, a total of four primary scenarios were proposed and analysed to determine the optimum development required to cover the period up till the year 2035, with a first phase of development intended to cover the water source requirements till the year 2017. Potential new water sources that were included in these scenarios are indicated in **Table 8-5**~~Table 8-5~~. All of these different scenarios included the development of the Northern Collector Tunnel Phase 1. The existing and potential new water sources can be compared with the projected demand from the Nairobi area for the period up to the year 2035 (Source: Water Sources Options Review (August 2011)

Table 8-6~~Source: Water Sources Options Review (August 2011)~~

~~Table 8-6~~).

The groundwater contributions to Nairobi Water Supply for both domestic, commercial or industrial purpose via public, private or individual boreholes and wells was considered to be about 45,000 m^3/day with a potential to grow by 1,000 m^3/day per year till the 2035 horizon. Two new well fields in Kiunyu (Thika) and Ruiru have been identified with potential yields of 34,560 m^3/day and 30,240 m^3/day respectively. Test boreholes require to be drilled to confirm these estimated yields.

Another water source which can be used in the long term is the recycling of wastewater. This option was considered by the Water Sources Options Review to be relatively expensive, and not a realistic option to be considered for significant development in the short-term. The level and types of treatment required for this option would be dependent on the various uses of recycled water. However the future use of wastewater is an option that does need to be considered. Another option for indirect use of treated wastewater is to recharge aquifers or to contribute towards the replenishment of surface water reservoirs. Similarly, the option of transfer of treated wastewater back to Tana catchment can provide the additional benefits of returning water for generation of hydropower. These options have to be studied in detail under the Proposed Sewage Master Plan. Treated wastewater can be used in a number of ways:

- Agricultural purposes, including irrigation,
- Industrial Use,
- Supplementing Potable Water Supply from other Sources,
- Environmental use, including the recharge of aquifers or replenishment of reservoirs.

An additional source of water for household use is the use of roof catchments for rainwater collection at an individual household level, or on individual buildings.

Table 8-5: Potential New Water Sources Identified

Proposed Development	Yield (m^3/d)	Remarks
Groundwater well fields	**64,800**	**Development of potential well fields in Kiunyu & Ruiru areas.**
Northern Collector Tunnel – Phase I	**138,240**	**Diversion and transfer from Irati, Gikigie and Maragua Rivers**
Northern Collector Tunnel – Phase II	**151,200**	**Diversion and transfer from South Mathioya, Hembe, Githugi & North Mathioya Rivers. Requires prior development of Northern Collector Phase 1**
Maragua 4 Reservoir	**45,792**	**Maragua Dam yield dependent on cross basin transfer and varied for different Scenarios**
Ndarugu 1 Reservoir	**397,440**	**With Chania - Komu River Transfer, (300 Mm^3 Storage).**
Total	**797,472**	

Source: Water Sources Options Review (August 2011)

Table 8-6: Water Demand Forecast: Nairobi City

	Year	2010	2017	2020	2030	2035
Population Projections						
Low Scenario	**Population**	**3,250,338**	**4,035,762**	**4,398,910**	**5,687,515**	**6,438,453**
	Growth Rate	**3.6%**	**3.1%**	**2.9%**	**2.6%**	**2.5%**
Medium Scenario	**Population**	**3,257,615**	**4,107,466**	**4,517,800**	**6,086,401**	**7,063,903**
	Growth Rate	**3.8%**	**3.4%**	**3.2%**	**3.0%**	**3.0%**
High Scenario	**Population**	**3,260,647**	**4,193,984**	**4,666,816**	**6,555,578**	**7,783,445**
	Growth Rate	**3.9%**	**3.7%**	**3.6%**	**3.5%**	**3.5%**
Population Served by Public Water Service Provider (Individual Connections)						
Percentage as I.Cs		**65%**	**68%**	**72%**	**78%**	**80%**

Water Demand Forecast, m3/d					
Low scenario	581,912	728,293	802,206	1,053,452	1,198,674
Medium scenario	582,928	740,870	823,488	1,126,797	1,314,493
High scenario	583,351	756,322	850,479	1,213,417	1,448,104

Source: Water Sources Options Review (August 2011)

The Water Sources Options Review Report (August 2011) established four main scenarios for development of water sources to meet the demand up to the year 2035. The proposed scenarios involve the combination in different manners and following various implementation schedules of the following water resources and main water schemes for the infrastructure (diversion / storage / treatment / transmission / etc.):

- Northern Collector Phase I with two sub-alternatives (whole collector from Maragua R. to Thika reservoir, or only from Irati R. to Thika reservoir);
- Diversion from S. Mathioya to Maragua River either to supplement the Northern Collector Phase I then Thika reservoir or to Maragua 4 reservoir; in the proposed scenarios this is a first step for the implementation of Northern Collector Phase II;
- Northern Collector Phase II either connected to Northern Collector Phase I to supplement supply to Thika reservoir or to Maragua 4 reservoir;
- Ndarugu 1 Dam on Ndarugu River;
- Diversion and transfer from Chania River to Komu River to supplement Ndarugu 1 reservoir.

The mobilisation of additional water resources will require additional water transmission facilities towards Nairobi City. These facilities are linked to new water treatment facilities with characteristics depending of each scenario and variant as follows:

- New Water Treatment Works located in Ndunyu Chege: could be supplied either from Thika Dam via the second offtake, from Maragua 4 Dam or from both. Downstream the treated water would be transferred to Gigiri Reservoir
- New High-Level Water Treatment Works located at Ngorongo: it would be supplied from Thika Dam second offtake by gravity; then the treated water could supplied to Kabete Reservoir per gravity
- New Water Treatment Works in Ndarugu; then treated water is pumped to Gigiri Reservoir.

The four scenarios are detailed in the Water Sources Options Review, and included the following phased developments:

Scenario 1:

- Phase 1: Well fields development in Kiunyu then in Ruiru areas;
- Phase 2: Northern Collector Phase I to Thika reservoir;
- Phase 3: Maragua 4 Dam and transfer from South Mathioya River to Maragua River;
- Phase 4: Northern Collector Phase II beyond South Mathioya River connected to Maragua 4 Reservoir;
- Phase 5: Ndarugu 1 Dam with natural inflow;
- Phase 6: Transfer from Chania River to Komu River to supplement inflow to Ndarugu 1 Reservoir.

Scenario 2:

- Phase 1: Well fields development in Kiunyu then in Ruiru areas;
- Phase 2: Northern Collector Phase I to Thika Reservoir;
- Phase 3: Northern Collector Phase II to NCI and Thika Reservoir;
- Phase 4: Ndarugu 1 Dam with natural inflow;
- Phase 5: Transfer from Chania River to Komu River to supplement inflow to Ndarugu 1 Reservoir.

Scenario 3:

- Phase 1: Well fields development in Kiunyu then in Ruiru areas;
- Phase 2: Northern Collector Phase I to Thika Reservoir;
- Phase 3: Maragua 4 Dam and South Mathioya River transfer to NCI and Thika Reservoir;
- Phase 4: Northern Collector Phase II to S. Mathioya River and to Maragua Reservoir;
- Phase 5: Ndarugu 1 Dam with natural inflow;
- Phase 6: Transfer from Chania River to Komu River to supplement inflow to Ndarugu Reservoir.

Scenario 4:

- Phase 1: Wellfields development in Kiunyu then in Ruiru areas;
- Phase 2: Northern Collector Phase I (from Irati River only) to Thika Reservoir;
- Phase 3: Maragua 4 Dam and South Mathioya River transfer to Maragua River;
- Phase 4: Northern Collector Phase II to S. Mathioya River to supplement inflow to Maragua Reservoir;
- Phase 5: Ndarugu 1 Dam with natural inflow;
- Phase 6: Transfer from Chania River to Komu River to supplement natural inflow to Ndarugu 1 Reservoir.

The advantages and disadvantages of the different development scenarios were evaluated by the Water Sources Options Review considering the objectives of the water supply strategy. The full comparison of the different scenarios was carried out on the basis of Multicriteria Analysis, including Environmental Impacts, and Least Cost Analysis to compare each of these potential water resources development scenarios. Comparison of each water source development scenario showed that overall Scenario 2 scored higher than the other scenarios.

Advantages of Scenario 2

As summarised in the Water Sources Options Review, Scenario 2 presented the following advantages against the other water sources development scenarios:

Meeting the 2035 Projected Water Demand: The water sources development phases of Scenario 2 ensure the production of additional water resources to meet the projected 2035 water demand. The phasing of infrastructure development ensures that the projected demand is continuously met from 2016 until 2035.

Security on the Water Source: Scenario 2 does not include the development of Maragua 4 storage dam and is mainly based on water sources abstracted from run-off rivers. Consequently it is assessed as having a higher risk of not meeting demand during extended droughts compared with the other scenarios. However, without Maragua 4 dam it was considered that there will be fewer downstream environmental and social impacts.

Diversification of Water Sources and Reliability: Scenario 2 will develop three additional major water sources and three additional routes for Nairobi water supply: one new gravity system will convey water from Thika dam storage to the new Ngorongo high level water treatment works to the Kabete Reservoir WTW. The second system will use the Nadarugu storage dam resources, while the third will involve the development of groundwater resources.

This option does not require the transfer of water from Gigiri to Kabete Reservoir, therefore saving on annual pumping costs.

Least cost for Additional Water: Investments under scenario 2 presented the second lowest least cost per m^3 of additional water over the 2011-2035 period, with an estimated AIEC of 0.63 USD/m^3 of treated water brought to the main reservoirs of Nairobi. The Present Value of Economic Costs for Scenario 2 was the lowest at US$ 824. The Capital Expenditure of Scenario 2 was approximately 12.5% lower than the Capital Expenditure of Scenario 3a which was the second best Scenario under the Multi-Criteria Weighting Analysis.

Impact of Water Abstraction on Other Uses: Impact of each scenario on natural resources, environment and alternative water uses was considered in the multicriteria analysis. When including the impact of water abstraction on downstream hydropower, scenario 2 has the second lowest economic cost of hydropower water abstraction. In addition the impact on Tana downstream HP dams can be compensated by a water transfer though the proposed Athi-Thika tunnel.

9 Environmental Monitoring Plan

In order to fully achieve mitigation of potential impacts, it is necessary to monitor actual impacts and the mitigation measures that are incorporated, and to adapt management strategies based on the results of monitoring. The Environmental Monitoring Plan (EMP) will need to be developed in detail alongside the detailed designs for individual components of the programme.

The objectives of the Environmental Monitoring Plan include:

- Ensuring compliance with relevant regulatory authority requirements and guidelines. These may be national and/or international.
- Ensuring that the allocation of project resources and budget are sufficient so that the scale of EMP-related activities, e.g. mitigation, is consistent with the potential significance of impacts.
- Verifying environmental performance through recording of information on impacts as they occur.
- Responding to changes in project implementation that may not have been considered in the EIA.
- Responding to unforeseen events, and changes in circumstances.
- Providing feedback for continual improvement in environmental performance.

The Environmental Monitoring Plan will need to include recommendations that the following be monitored:

- Regular monitoring of flows upstream and downstream of all diversion structures and storage reservoirs. This will also include the monitoring and reporting of the volume of Reserve Flows, including both Environmental Flow and Compensation Flow components.
- Monitoring of sediment loads at intake weirs and downstream of intakes.
- Periodic surveys of aquatic fauna upstream and downstream of the intake weirs, as well as in Thika reservoir. These surveys should be designed to deliver an up-to-date and comprehensive assessment of the aquatic and riparian communities, to create a baseline, to monitor changes, and to allow for subsequent monitoring of impacts on these communities. Surveys should include both native and introduced species.
- Changes to riparian vegetation downstream of the intake weirs.
- Changes in demand for water downstream of the intakes. This should include household water supplies with changes in household numbers and population densities, as well as changes in demand related to increased demand for agricultural production (including small scale irrigation, commercial irrigation and livestock requirements).
- Changes in the quality and availability of water supplies from rivers and associated streams and impacts on public health, including those communities dependant on downstream flows. This should include regular testing for chemical pollution from agricultural inputs upstream of intake points, as well as monitoring of potential faecal-bacterial pollution and other communicable disease health risks.
- Land use and land cover, including forest cover in the Aberdares catchment area, as well as agricultural activities in the catchment areas of the rivers associated with the Northern Collector phase 1, and the catchment of Thika Reservoir.

In order to achieve the above objectives, the Environmental Monitoring Plan should also include:

- Definition of the environmental management objectives to be followed in order to enhance benefits and minimise adverse impacts, including during construction and operational phases.
- Description of the actions needed to achieve these objectives, including by whom, and with what resources, as well as necessary monitoring or verification.
- Consideration should also be given to address possible changes in the project implementation, emergencies or unexpected events.

Construction Phase

Separate EMPs should be prepared for Construction and Operational phases. Construction Environmental Management Plans will be required to deliver a practical and achievable plan of management and to ensure that potential environmental impacts during the construction phases are minimised. Plans will need to be developed prior to construction, but can only be proposed once sites are finalised and full design and construction details are available. The following issues will need to be included:

- Physical setting, flora and fauna, ensuring minimal environmental impact and proposing mitigation measures, including the setting aside of alternative terrestrial and aquatic habitats for preservation to compensate for loss of habitats;
- Prevention of interruption to existing infrastructure installations and services, including the building of alternative access routes as required;
- Resettlement and land compensation, including compensation for potential loss of livelihoods;
- Ensure that noise and vibrations are kept to acceptable standards, including the impacts from blasting associated with construction activities for tunnels;
- Water quality management, dust and air quality, soil and groundwater contamination control
- Waste management, land contamination, erosion and sediment control, and
- Environmental Performance Monitoring.

Operational Phase

Operational Environmental Management Plans will also be required. These should focus on sound environmental management practices undertaken to minimise adverse impacts on the environment during normal operation of the intake sites, reservoirs and water transmission tunnels and pipelines. The following issues will need to be included:

- Overall management strategy, including environmental performance monitoring and regular reporting. It is recommended that a scientific advisory committee be established to aid with long-term environmental monitoring.
- Maintenance of environmental integrity, including the provision of adequate downstream Reserve Flows:
    a) Provision, maintenance and monitoring of Environmental Flows,
    b) Preservation of those habitats that depend on these flows,
    c) Provision, maintenance and monitoring of Compensation Flows for downstream communities affected by reduced flows,

d) Provision, maintenance and monitoring of flows required for purposes of downstream agricultural production, including irrigation, livestock, and the needs of factories (e.g. tea and coffee), and

e) Preservation of water quality standards, including the minimization of potential impacts on public health.

- Minimization of leakages in transmission pipelines and in the distribution pipeline network.
- Energy management, including measures to ensure minimizing greenhouse gas emissions.

Environmental Monitoring Plans may also be required for areas of specific ecological or social value, for example to ensure preservation of potentially important habitats or social amenities that may form part of the planned route for the proposed pipeline from Thika Reservoir to the treatment works, or other pipeline routes.

9.1 Draft Environment Management Plan

There are three main elements or phases to the environment management plan. During the pre-construction phase important baseline information will need to be collected and this will form the basis for environmental monitoring during the subsequent construction and operational phases. The environment management plan in the construction phase will require to focus on detailed monitoring of potential impacts and on mitigation and/or compensation for impacts.

Pre-Construction Phase

An important task in the pre-construction phase will be to set up a series of important monitoring systems that will be capable of providing the important critical required during the construction phase and also during the subsequent operational phase. Chief amongst these are the establishment of additional river gauges required to provide important information on the downstream flows so as to ensure adequate Reserve Flows, together with an up-to-date and complete listing of all abstractions of water from the Irati, Gikigie and Maragua rivers – including both licensed and unlicensed abstractions. Regular daily monitoring of all flows will be required and a system for rapid reporting of these flows, perhaps by mobile phone systems, so that adequate downstream Reserve Flows can be maintained – including both environmental and compensation flows.

In addition, there will need to be surveys of aquatic and riparian fauna upstream and downstream of the intake weirs, as well as aquatic fauna in Thika Reservoir. These surveys will provide up-to-date assessment of the aquatic and riparian communities, and will create a comprehensive baseline from which to monitor changes and potential impacts on these communities. Surveys should include both native and introduced species. Surveys of aquatic fauna should include surveys of fish species present in the Maragua, Gikijie and Irati Rivers, and in Thika Reservoir and Thika River. Surveys of riparian fauna should include seasonal surveys of bird species to determine the numbers of species and population numbers. These data on bird assemblages (including migratory species) will subsequently be used as indicators of riparian condition as components of environmental monitoring during construction and operational phases.

The management of disposal of material excavated from the Northern Collector tunnel will need to commence during the pre-construction phase. It is recommended that no permanent "spoil dumps" are used. Instead of considering the excavated material as "spoil" requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material, including the making of bricks for buildings. It is therefore recommended that on-site storage of excavated material should be minimized and that only temporary storage sites should be constructed within reach of each of the access sites. It is also recommended that the excavated material is transported away from the sites at a rate similar to the rate of extraction. The emphasis should be for the material to be transported for either temporary or permanent storage at suitable sites elsewhere.

Environmental Monitoring Plan

Table 9-1: Pre-Construction Phase Information Requirements

Information Requirements		**Actions, Surveys or Data Recording**
Monitoring of water resources	Adaptive water management needs reliable and comprehensive data on which to base decision making. These data should cover not just daily hydrological characteristics, but also indicators of water use and abstraction.	Upgrade existing and establish new river gauges for monitoring flows. River flow gauges spaced at not more than 10 km intervals downstream of the intake weirs and upstream of Masinga Reservoir. Establish systems for daily reporting of these data to a central system.
Monitoring of water use and abstraction	Monitoring of downstream water use by communities and industries is required. 1. Household use 2. Agricultural use 3. Industrial/commercial use	Up-to-date information on all abstractions from the rivers, including both licensed and unlicensed abstractions for all uses. Obtain data on volumes of water required as well as monthly or seasonal changes in requirements, and methods of abstraction.
Rural Water Supplies	Collection of up-to-date information on the status of rural water supplies to households as well as the numbers of households connected and not connected to rural water supplies.	Develop proposals for development of rural water supplies to ensure that as many as possible of the rural households in those areas downstream of the Maragua, Gikigie and Irati intakes are connected.
	Consideration should be given to ensure that all communities traversed by the pipelines are fully provided with piped water supplies, as a priority.	Provide adequate local, rural and urban water supplies along pipeline routes
Data for monitoring aquatic and riparian fauna	Monitoring for the EMP requires a set of accurate and comprehensive baseline data on which to base subsequent surveys, compare changes, and determine required actions. Where possible, surveys should include involvement of personnel from the National Museum.	Surveys of aquatic fauna, including fish species in the rivers and in Thika Reservoir. Development of detailed plans and designs for fish passes or fish ladders as integral components of each of the intake weirs. Surveys in the riparian zone of bird species and population numbers.
Resettlement Action Plan	The installation of the pipeline may result in displacement of households.	A Resettlement Action Plan should be prepared. Involuntary displacement should be avoided

Information Requirements		Actions, Surveys or Data Recording
Data on land use / land cover	Detailed information on the land use and land cover will be required as part of the EMP for all areas adjacent to the intake sites, outfall and other access sites for: 1. Northern Collector tunnel 2. Pipeline routes	Detailed land use and land cover surveys. These will form a baseline for environmental and social monitoring components of the Environmental Management Plan.
Disposal of excavated material	Instead of considering the excavated material as "spoil", requiring disposal, it should be used as raw material for a range of activities such as road repair and construction, and for use as building material.	Selection of suitable sites for long-term storage of excavated material. It is suggested that disused quarries should be used for storage of excavated material. It is also recommended that disposal of excavated material is integrated with the regeneration and rehabilitation of disused quarries.
Storage areas for excavated material	Construction of temporary on-site storage of material excavated from the tunnels will be required. Storage will need to be within fully bunded structures so as to prevent erosion and siltation in rivers.	Selection of suitable sites for temporary storage of excavated material. Purchase of the land and compensation of households for loss of future earnings from these areas. Storage sites will need to be constructed with at least 40 m buffer zone between the bunded storage area and the edge of the river.
Ambient air quality	Active sampling methods to determine air quality will be required.	Baseline sampling to determine ambient air quality will be carried out prior to the commencement of construction activities.
Baseline noise levels	Noise level measurements will be need to be carried out as per ISO standards.	Baseline sampling to determine noise levels will be carried out prior to the commencement of construction activities.
Technical committee	A technical committee, including environmental assessment personnel, needs to be established with the remit to assess any damage caused and assess required compensation or mitigation measures during construction and operational phases.	Establish technical committee and review the collection of baseline monitoring data. Ensure that contracts for the construction phase include reference to supervision by the technical committee. Ensure that all local communities are fully aware of the details of upcoming activities.

Construction Phase

Where the household property or productive assets (e.g. plantation tea) adjacent to the construction or operational sites are to be infringed upon or otherwise impacted, they should be sufficiently and promptly compensated for. Similarly, where property or productive assets are impacted by trucks or other transport associated with construction and excavation activities, sufficient compensation should be given. National guidelines for compensation rates should be followed as minimum compensation, including rates provided by the Ministry of Agriculture for the value of crops and trees. The value of tea plantation should also take account of the long term value of tea to household incomes in this area.

During the construction phase, the role of the contractor is critical. With specific reference to the Environment Management Plan (EMP), the role of the Contractor will be to:

- Implement, manage and maintain the construction elements of the EMP for the duration of the contract;
- Designate, appoint and/or assign tasks to personnel who will be responsible for managing the relevant components of the construction EMP, and assign appropriate authority, accountability and necessary equipment and facilities for these personnel to carry out their duties;
- Ensure that all sub-contractors and other workers appointed by the Contractor are aware of their environmental responsibilities while on site or during the provision of their services off site, and ensure that they comply with and implement the construction EMP during the duration of their specific contracts;
- Provide appropriate resources, including budgets, equipment, personnel and training, for effective control and management of all environmental risks associated with the construction phase.

Table 9-2: Environmental, Safety and Health Issues during Construction Phase

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
Technical committee	Continue the technical committee and review the collection of baseline monitoring data. Ensure that the technical committee is able to review information from continued environmental monitoring activities as well as all ongoing construction activities.	All involved Authorities and Construction management
River flows	Continued daily monitoring of flows upstream and downstream of all diversion structures on a daily basis, including at all new sites installed during pre-construction phase on Maragua, Gikigie and Irati Rivers. Monitoring of sediment transport at all river gauges.	Data collection
Water Quality	Monitoring of water quality, including tests for biological contamination that may be related to potential human health issues. Monitoring to be carried out at all river gauge sites.	Data collection, Health & Safety

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
Loss of land and changes in land cover	Monitor changes in land use and land cover, including: • Riparian vegetation • Forest and woodland, and individual trees • Smallholder tea plantation • Other agricultural areas, and areas that are suitable for and used by grazing livestock (e.g. sheep owned by the community) • Household land and adjacent community areas • Roads and tracks, including footpaths used by the community • Loss of access to land as a result of pipeline wayleave • Change in vegetation cover and land use along pipeline routes	Data collection
Establishment of Buffer Zones	Ensure that all construction activities are confined to within defined buffer zones.	Administrative
Awareness	Ensure that all construction personnel and supervision personnel are aware of the environmental requirements and are equipped to deal with these requirements. This should include relevant health and safety requirements.	Administrative
Site management	All areas should be securely fenced at least 3 m from the edge of operational areas using chain link fencing of at least 1.5 m high. Warning notices / signs erected at all entrances. All roads and tracks to be safely accessible. All footpaths and access to tea plantation lands to be safely accessible by local communities and landowners.	Administrative
Workmen's camps and Settlements	Ensure careful planning and location of both temporary campsites, and more permanent workmen's camps. Provide local employment. Provision of adequate sewage and waste disposal facilities, and adequate resources, including water supplies and household fuel. There may also be health risks and increased requirements for health services, including both first aid facilities and medical centres.	Construction management Administrative, Health & Safety

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
Health and Safety	Relevant protective gear and equipment should be used by all construction personnel, including: • Protective helmets • Gloves • Protective footwear • Safety goggles • Dust masks • Overalls/dust coats All blasting materials and all other potentially dangerous materials to be acquired, stored and used subject to relevant permits.	Administrative, Health & Safety
Safety Training	Operators to be trained on safety, health and environmental issues. Each construction site should have a person in charge of safety, and Safety, Health and Environment Committees should be established at each construction site. These should report to the Technical Committee.	Administrative, Health & Safety
Waste Disposal	**Waste collection and disposal pathways and sites will be identified for all major waste types expected from construction activities.** **Mineral construction waste will be separated from general refuse, organic, liquid and chemical wastes by onsite-sorting and stored in appropriate containers.** There will be no open burning of waste materials at the sites.	Administrative, Health & Safety
Welfare	Adequate welfare facilities to be provided at all sites, including clean water and sanitation, first aid kit with trained first aiders.	Administrative
Access Roads to NC tunnel access sites	Road maintenance to be carried out on a regular basis to ensure continued access for all local services. Road maintenance should make maximum use of material excavated from the tunnel.	Administrative
Pipelines and Access Roads	Impacts may occur where transmission pipelines cross roads. These impacts should be prepared for and included in detailed designs. Required mitigation measures should be incorporated in designs and action plans.	Construction management

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
Pipeline Access for Maintenance	Long-term access to the pipelines will be required for routine checking and maintenance. Careful location of pipelines will be required, and access incorporated in detailed designs.	Construction management
Noise Levels	Regular monitoring of noise levels. Reporting of unacceptable noise levels.	Data collection
Air Quality	Regular monitoring of air quality, including monitoring of dust levels near all excavated material storage sites, and reporting of unacceptable air quality levels so that appropriate actions can be taken by construction management.	Data collection
Habitat Restoration Required as a result of Clearance of Vegetation	Minimize clearance of natural vegetation. Ensure a buffer zone of a minimum of 30 metres between all construction sites or related activities and the riparian zone along the rivers. The only exception to this will be the construction of the intake weirs and associated structures. For every tree cut or felled, ensure that a minimum of five trees are planted and maintained elsewhere in suitable sites nearby along the river, either upstream or downstream of the intake sites. Creation of wildlife corridors to replace all areas where removal of trees or other vegetation has resulted in disruption to existing wildlife corridors. Habitat restoration in areas impacted by clearance of vegetation along the transmission pipeline routes.	Construction management
Monitoring of Habitat Restoration	All areas impacted by clearance of vegetation will require habitat restoration. This restoration should be monitored to ensure success and feedback of these findings must be provided to construction management to enable improvements where necessary.	Data collection and Construction management
Erosion	Monitor erosion and ensure adequate erosion control measures are in place	Data collection and Construction management

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
Pollution	Monitoring of pollution, including dust and noise pollution. Contamination from wastes and oil/fuel spills may also occur. All sites where oil or fuel may be stored should be protected by fully bunded structures to contain all potential spills. Such sites will require to be constructed with a buffer zone of at least 40 m between the fuel storage area and the edge of the river.	Construction management
Excavated Material	Finalise the construction of temporary on-site storage facilities for material excavated from the tunnels. Storage will need to be within fully bunded structures so as to prevent erosion and siltation in rivers.	Construction management
Storage of Excavated Material	On-site storage of excavated material will require the construction of fully bunded structures to contain all of the excavated material so as to prevent erosion and siltation in the rivers, constructed at least 40 m buffer zone between the bunded storage area and the edge of the river. Storage areas should avoid areas being close to tea plantations due to the potential problems related to contamination of tea with dust from excavations. Storage areas should avoid being located on steep slopes due to the potential problems of erosion.	Construction management
Transport of Excavated Material	Ensure that there is sufficient transport to enable transfer of excavated material from temporary on-site storage areas to permanent facilities that have been prepared elsewhere.	Construction management
Hydrogeology	Tunnelling may result in changes to underground drainage as a result of underground fractures. This will require detailed investigation during construction. The wider impacts of changes in underground drainage on groundwater resources will also need to be investigated, and suitable mitigation measures developed and implemented.	Data collection and Construction management

Operational Phase
Impacts that can be expected from operation of the intake weirs are listed in Table 8-3Table 8-3. Primary environmental impacts resulting from operation of the intake weirs and Northern Collector Tunnel are related to the significant change in downstream hydrology. These will result from changes to water flow patterns, changes in quantity (in particular the loss of flood events), and also from a deterioration in water quality. Changes in water quality are themselves a direct response to the changes in flow. In addition, the normal or base flows

will, after installation of the intake weirs and abstraction of water, change to the flows similar to those currently classified as "extreme low flows", or to the lower range of flows classified as low flows, or base flows.

The provision of adequate downstream environmental flows, as a component of Reserve Flows, is considered to be essential for all rivers, as described under "Downstream Reserve Flows". Similarly, provision of adequate compensation flows is viewed as being critically important for all downstream communities.

An important consideration will be the cumulative impact arising from the combined operation and release of downstream Reserve Flows from all three weirs at Maragua, Gikigie and Irati. Cumulative impacts are likely to include the following factors (see also section 6 on Cumulative Impacts):

- Less flow available for use in current and future agricultural activities, especially for use during dry seasons, in order to provide food required by the increasing population of Nairobi.
- Reduction in the flow reaching Masinga Reservoir.
- Short periods or single days with zero flow, preceded and/or followed by further periods with extreme low flow.

Up-to-date information on all downstream abstractions from the rivers, including both licensed and unlicensed abstractions for all uses (including: household, agricultural / irrigation, industrial uses, and methods of abstraction) should continue to be obtained, following on from the collection of this information as part of the EMP during pre-construction phase. These data will need to be monitored and updated on a regular basis and the requirements for downstream Reserve Flows modified accordingly.

Monitoring surveys initiated as part of the EMP during the pre-construction phase should continue to be conducted on a regular basis. These include surveys to determine changes that may occur within aquatic and riparian habitats. Where such changes are related to reduced downstream flows, it may be necessary to either adjust the levels and timing of environmental flows accordingly, e.g. though the provision of high flow pulses, or to carry out alternative mitigation or preservation measures.

In those cases where there are a number of different relevant Authorities for management or control of specific issues raised by the Environment Monitoring and Management Plan, it will be necessary to establish Technical Committees and Working Parties with representatives from each of the different authorities. Examples may for example include the monitoring of downstream flows and the setting of or modifying Reserve Flows, including both Environmental Flows and Compensation Flows. In this case, different Authorities may be responsible for the monitoring and recording of daily flows, for Nairobi water supplies, for the licensing of abstractions (and recording of all licensed and unlicensed abstractions), for the use of water for irrigation of smallholder and/or commercial agriculture, household and rural water supplies, and for environmental flow requirements, as well as for downstream hydropower use at Masinga Dam or mini-hydro schemes and other downstream needs.

Table 9-3: Environmental Issues during Operational Phase

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority

Environmental and Social Issues	Environment Monitoring and Management Requirements and Mitigation Measures	Type of Action or Authority
River Flows	Continued daily monitoring of flows upstream and downstream of all diversion structures on a daily basis, including at all new sites installed during pre-construction phase on Maragua, Gikigie and Irati Rivers. Monitoring of sediment transport at all river gauges.	Data collection
Reserve Flow Requirements	Continued assessment of the abstractions by downstream water users (both licensed and unlicensed) will be required on a regular basis, including monthly or seasonal abstraction requirements.	Data collection
Rural Water Supplies	Ensure that all abstraction sites for rural water supply systems are supplied with adequate flows.	Management of the Intake Sites.
Irrigation Requirements	**Ensure that downstream irrigation requirements are** supplied with adequate flows.	Management of the Intake Site
Groundwater levels	**As a result of reduced downstream flows there may be a reduction of recharge to groundwater from the impacted rivers.** **Changes in groundwater levels may also occur as a result of extraction of water that the proposed well fields. It will be necessary to install an increased network of river gauges and recording stations in order to cover the potentially impacted areas. Regular, daily monitoring and reporting of these river gauges will be necessary.** Existing springs and dug water supply wells in the areas within the geological strata affected by the proposed groundwater well fields will need to be identified and mapped. The yields from these sources will need to be recorded and monitored. Alternative, piped, water supplies will need to be provided in those cases where these water sources are impacted by reduced groundwater levels resulting from abstraction	Data collection.

Environmental and Social Issues	**Environment Monitoring and Management Requirements and Mitigation Measures**	**Type of Action or Authority**
Provision of Downstream Reserve Flows	Based on the assessment of downstream water use requirements, adjust the provision of Reserve Flows to ensure adequate provision of water resources for all downstream users, whilst at the same time maintaining adequate environmental flows. Ensure that there are no unnecessary periods with unacceptable low flows or zero flows in downstream reaches of the rivers. At such times, increased release of flows at the intake sites (derived from forested areas of the Aberdares) is likely to correct these potential problems. In some cases it may be necessary to restrict abstractions by selected downstream users in order to ensure maximum provision of water resources to downstream communities.	Management of the Intake Sites.
Water Quality	Monitoring of water quality, including tests for pollutants and biological contamination that may be related to potential human health issues. Monitoring to be carried out at all river gauge sites on a regular monthly basis.	Data collection, Health & Safety
	Reduced nutrient availability in downstream areas, resulting from the reduction in downstream flows, may result in a reduction in productivity of downstream systems, including cultivation in alluvial and other riparian areas downstream. In such cases it may be necessary to carry out mitigation or corrective measures, for example through the release of high flow pulses or flood events to induce sediment transport.	Data collection. Actions to be taken by Relevant Authorities.
	Reduced water quality as a result of reduced flows may result in increased health risks for downstream communities especially for those households dependant on untreated river water. A change in faecal bacterial concentrations and waterborne pathogens as a result reduced flows and from inflow of contaminants from upstream is likely and needs to be monitored.	Data collection. Actions to be taken by Relevant Authorities.

Environmental and Social Issues	**Environment Monitoring and Management Requirements and Mitigation Measures**	**Type of Action or Authority**
Changes to Aquatic and Riparian Habitats	**It will be necessary to continue regular monitoring of riparian habitats, and surveys of aquatic fauna and bird populations in riparian zones. Results of these surveys will provide indication of potential changes or loss of habitat downstream as a result of changed hydrological regimes, including cumulative downstream impacts. Depending on the nature and specific locations of observed changes, those management authorities concerned with the maintenance of riparian zones will need to propose and carry out mitigation or corrective measures. These may for example include release of environmental flows that include high flow pulses.**	Data collection. Actions to be taken by Relevant Authorities.
Increased Settlement	**Increased permanent settlement is likely to result from activities during the operational phase. In addition to operational staff, induced settlement is likely to occur in the surrounding area, creating potential stress on local resources and facilities, including fuelwood.**	Intake Site Management Authorities.
Impact from presence of pipelines	**Long-term access to the pipelines will be required for routine checking and maintenance. Assuming that most of the pipeline length is buried with limited surface structures, the overall impacts can be expected to be relatively low. However, leaks are highly likely to occur along transmission and distribution pipelines, and possibly at treatment works. Contamination of supply pipes may also occur at these sites. Leakages may result in health risks, e.g. Malaria, Cholera, Typhoid, Dysentery, Diarrhoea and other water-borne or water-related diseases. All leaks should be monitored and controlled accordingly.** Regular monitoring and maintenance is considered essential. **Early detection of leaks reduces the possibility of public health risks.**	Pipeline Management Authorities.